A Study of Arsenic Leaching from Colloidal Silver Ceramic Water Filters Manufactured in Myanmar

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Safe Water Systems

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The consultant would like to sincerely thank the 9 manufacturers of ceramic water filters on Myanmar for each providing sixteen filters to be used in this study. The consultant would also like to thank ThirstAid, Myanmar for facilitating the collection and delivery of these filters to Safe Water Systems in Yangon.

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Special thanks also goes to Richard Tracey, the WASH Coordinator for Action Contre La Faim (ACF), Myanmar for providing technical assistance and advice in the design and implementation of this study as well as for the editing of this report.

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Executive Summary

Myanmar's first colloidal silver ceramic water filter factory was established in 2003 by Lilypad who replicated a model developed by International Development Enterprises (IDE) in Cambodia. This factory produces the classic bucket shaped design first promoted by Potter's for Peace in Central America in the mid-90s.

Round-bottomed, colloidal silver ceramic water filters have been manufactured in Myanmar since 2006, when ThirstAid and UNICEF supported the establishment of a factory operated by the Community Development Association (CDA) in Shwe Pyi Thar, Yangon Division. The following year a second factory, Zawgii was established in Twantay Township, Yangon Division. In the first 18 months of production, sales of ceramic water filters were modest. However, in the aftermath of the Nargis cyclone, the WASH cluster endorsed the use of ceramic water filters as an effective strategy for the promotion of safe water at the point of consumption during both the emergency response and early recovery phases of the disaster response and sales mushroomed.

In the 18 months since the Nargis cyclone, over 115,000 ceramic water filters have been distributed to households in the Delta and the number of ceramic water filter factories in Myanmar has increased to a total of 9 factories. Currently, Myanmar has the fastest growing ceramic water filter industry in the world.

Although the distribution of ceramic water filters has been strongly promoted by both donors and agencies alike, questions has been raised by a number of agencies concerning a potential health risk that might be posed by ceramic water filters as a result of arsenic leaching from the filters. The alarm was first raised in Myanmar by International Committee of the Red Cross and Red Crescent (ICRC) who published a report in 2006 which revealed that arsenic was leaching from the filters. The issue was again formally raised by Oxfam in March 2009 who published a report highlighting the fact that arsenic had been observed to leach from new filters and again questioned a potential health risk.

In response to these findings, UNICEF commissioned Safe Water Systems to conduct a 3-month study to determine amongst other things, whether or not the leaching of arsenic from colloidal silver, ceramic water filters posed a significant health risk to users.

The other objectives of the study were:

- To determine the concentration of arsenic leached from the ceramic water filters produced by the 9 manufacturers in Myanmar
- To determine the change in arsenic concentration leached from CWF with increasing cumulative volume of filtered water
- To determine whether the colloidal silver coated on the filters affects the leaching of arsenic from the filters
- To determine the effect of pre-soaking on arsenic leaching from CWF
- To identify the source of the arsenic leached from ceramic water filters

Based on the evidence presented in this study, the consultant does not regard the risk of arsenic exposure from the leaching of ceramic water filters to be a significant health risk to users. The study confirms the observations published by both ICRC (2006) and Oxfam (2009) stating that significantly high levels of arsenic are released by ceramic water filters in the first stages of use. However, the highest concentrations observed were 200ppb for 2 single litre samples from 2 of the 46 filters [4%]. Once these samples were mixed with filtered water from the next few litres of use, the overall arsenic concentration reduced to levels below the maximum guideline value for countries most affected by arsenic of 50ppb. These usually high concentrations of arsenic tended to be released during the first 20-litres of operation. Consequently, if the first 20-litres of filtered water is discarded before the filters are commissioned for household consumption, as recommended by both manufacturers and implementing agencies, the risk of exposure dramatically reduces to acceptable levels.

It was not possible during this study to determine the origin of the arsenic. However, in the consultant's opinion, the majority of the arsenic is highly likely to originate from the rice husks used to create the porosity in the filters based on tests conducted by Community Development Association (CDA) in Yangon.

The study was able to conclude two additional findings, that the leaching of arsenic does not appear related to the colloidal silver coating painted on ceramic water filter to kill harmful pathogens and that the theory, suggested by International Development Enterprises (IDE), Cambodia, that arsenic leaching could be prevented by soaking the filters under water for 72 hours does not appear to apply to filters manufactured in Myanmar. Soaking the filters over a 168-hour period had little additional effect on reducing the leaching that would normally be observed in the first 20-litres of use.

A Study of Arsenic Leaching from Colloidal Silver, Ceramic Water Filters manufactured in Myanmar

Introduction

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Although the distribution of ceramic water filters has been strongly promoted by both donors and agencies alike, questions has been raised by a number of agencies concerning a potential health risk that might be posed by ceramic water filters as a result of arsenic leaching from the filters. The alarm was first raised in Myanmar by International Committee of the Red Cross and Red Crescent (ICRC) who published a report in 2006 which revealed that arsenic was leaching from the filters. The issue was again formally raised by Oxfam in March 2009 who published a report highlighting the fact that arsenic had been observed to leach from new filters and again questioned a potential health risk.

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Objectives of the study

The proposal submitted to UNICEF listed 5 objectives for the study:

- To determine the concentration of arsenic leached from the ceramic water filters produced by the 9 manufacturers in Myanmar
- To determine the change in arsenic concentration leached from CWF with increasing cumulative volume of filtered water
- To identify the source of the arsenic leached from ceramic water filters
- To investigate whether any other toxic metals leach from CWF (cadmium, copper, zinc, mercury, lead).
- To determine the effect of pre-soaking on arsenic leaching from CWF

However, these objectives were based on the assumption that it would be possible to procure and gain access to appropriate technical equipment necessary to achieve these objectives. Unfortunately, for reasons beyond the control of Safe Water Systems, it was not possible to obtain access to certain equipment (see the section on limitations and constrains for details) and so an amendment was made to the original proposal revising the objectives of the study to the following:

- To determine the concentration of arsenic leached from the ceramic water filters produced by the 9 manufacturers in Myanmar
- To determine the change in arsenic concentration leached from CWF with increasing cumulative volume of filtered water
- To determine whether the colloidal silver coated on the filters affects the leaching of arsenic from the filters
- To determine the effect of pre-soaking on arsenic leaching from CWF
- To identify the source of the arsenic leached from ceramic water filters

Method

Each factory provided Safe Water Systems with 16 filters for this study; 15 filters coated in colloidal silver and 1 filter per factory without colloidal silver. Of the 15 filters with colloidal silver, 5 filters were chosen at random on which to conduct the main study on arsenic leaching.

46 ceramic water filters were suspended from a wooden cradle and two sizes of containers used to collect the filtered water; a 1-litre measuring cylinder and a 30-litre plastic bucket. Yangon city water supply was used as the raw water source as following testing, this water proved to be free from arsenic contamination.

At the beginning of the experiment a 1-litre measuring cylinder was placed beneath each ceramic water filter. Once the measuring cylinder had been filled with 1-litre of filtered water, the container was replaced by a 30-litre bucket to ensure that all the filtered water was collected throughout the experiment.

The contents of the 1-litre measuring cylinder was mixed thoroughly and the arsenic concentration determined using a WagTech digital arsenator. The 1-litre sample was then added to the 30-litre bucket collecting the filtered water for first 10-litre sample. Once the contents of the bucket reached 10 litres, the bucket was removed and replaced by the 1-litre measuring cylinder. The contents of the bucket (10 litres of filtered water) was mixed thoroughly, the arsenic concentration determined and the contents of the bucket thrown away.

As it was assumed that arsenic leaching occurs in the greatest concentrations in the early phases of operation, 10-litre samples were taken for the first 50 litres of operation (0-50 litres) while 20-litre samples were taken for next 100 litres of use (50-150 litres). As explained above, the first litre of each of the 10 litre and 20 samples were collected separately, the arsenic concentration determined and then added to the larger sample.

For each filter a total of 20 samples were taken and the arsenic concentration determined; 10, single-litre samples, five, 10-litre samples and five, 20-litre samples:

Single litre samples	10-litre and 20-litre samples
1st litre	0-10 litres
11th litre	10-20 litres
21st litre	20-30 litres
31st litre	30-40 litres
41st litre	40-50 litres
51st litre	50-70 litres
71st litre	70-90 litres
91st litre	90-110 litres
111th litre	110-130 litres
131st litre	130-150 litres

To determine whether the colloidal silver had any affect on arsenic leaching the above experiment was conducted on 10 filters that were not coated with colloidal silver and the results compared to filters coated in colloidal silver.

Limitations and Constraints

A WagTech Equipment

It was the intention of Safe Water Systems to conduct this study using a new product from WagTech International; a WagTech Metalyser HM 1000 portable heavy metals analyzer. The Metalyser is a multi-probe device capable of determining concentrations of 6 heavy metals within 5 minutes per sample. The metalyser tests for arsenic, zinc, mercury, cadmium, copper and lead.

The product was due for commercial release in June 2009. However, once the product was being scaled up from the prototype to commercial production, a fault was noticed with one of the gold electrodes and consequently, WagTech will not release this new product until early 2010; too late for it to be used in this study.

As it was not possible to use the Metalyser HM 1000 to determine the concentration of heavy metals, it was decided for this study to focus solely on arsenic leaching. To determine the concentrations of arsenic, a WagTech digital arsenator was used. Tests conducted at an Indian university claim the unit is capable of accuracy to within 1ppb. However, in the middle of this study, WagTech alerted the consultant to a minor fault with the digital arsenator that the consultant had not previously been aware of and which may have slightly affected results obtained in the early stages of this study. On occasions, the arsenator will read the blank filter strips onto which the arsine gas is absorbed during the test as being approximately 2ppb. Consequently, it is necessary to zero the arsenator for each use using the blank filter paper strip used to conduct the test. This means that it is only possible to conduct one test at a time and as it takes a minimum of 25 minutes per test, this meant that this study took considerably longer to conduct than expected.

B Atomic Absorption Spectrometer

It was the original intention to determine the origin of the arsenic leaching from the ceramic water filters. In order to do this, it is necessary to analyze samples of the raw materials used to make the filter; the clays, the rice husks and the sawdust using an atomic absorption spectrometer. The only places to have such a unit in Myanmar are government facilities. Unfortunately, during this study the Myanmar government restricted the use of such machines and permission is now required from the central government level in Nay Pyi Daw. As it was not possible to obtain permission during the short timeframe of this study, it was consequently not possible for the consultant to determine the origin of the arsenic leaching from the ceramic water filters

C Sample size

It was intended to use a sample size of 10 ceramic water filters from each or the nine factories to conduct the main experiment on arsenic leaching. Had the WagTech Metalyser 1000 HM been commercially available each test for all 6 heavy metals would have taken 5 minutes. However, by using the WagTech digital arsenator, the time taken for one test was increased to a minimum of 25 minutes per arsenic test. As each filter requires 20 tests, it would take 750 hours to conduct the arsenic tests. Consequently, it was necessary to reduce the sample size to 5 filters per factory to ensure the study was completed within the timeframe.

D Average arsenic concentrations

Although every effort was taken to thoroughly mix each sample before taking the 50ml required to conduct each test, the sample used to make the test may not have been fully representative of the total sample.

Results and Findings

A Does arsenic leach from ceramic water filters at a constant rate?

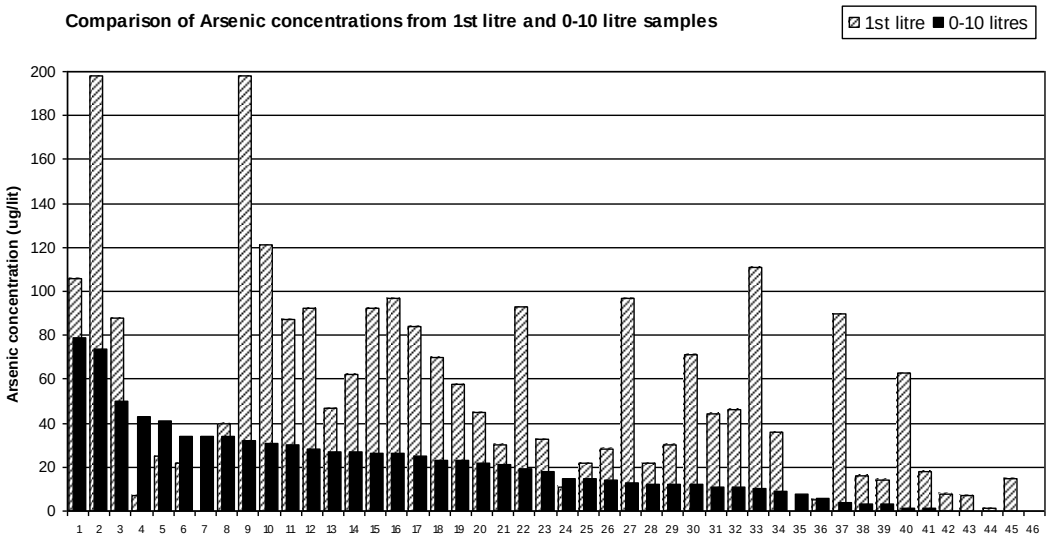
A study conducted by International Development Enterprises (IDE) in Cambodia investigated arsenic leaching from colloidal silver ceramic water filter manufactured from 3 factories in central and southern Cambodia. The study concluded that arsenic levels were highest during the early periods of use, with average concentrations 250-350 pbb but steadily reduced to levels below the maximum WHO guideline value of 10ppb after 250-350 litres of use.

Evidence presented in an MSc research dissertation conducted in Cambodia (2001)[1], where colloidal silver ceramic water filters were tested to learn whether they had arsenic removing properties, noted that although in their early stages of use the filters appear to remove arsenic from contaminated source water, when the filters become saturated with arsenic, dangerously high levels of arsenic are released in high concentrations and consequently the filters were rejected as a potential method for mitigating arsenic contamination from groundwater. Based on this observation, it was assumed that the leaching of arsenic from the ceramic water filters manufactured in Myanmar, would not occur at a steadily reducing rate but more likely be spontaneously released in higher concentrations during use.

To prove this hypothesis, two types of samples were taken during the experiment; single litre samples taken at key points during the first 150 litres of filtration and larger samples taken consecutively throughout the experiment which measured the total quantity of arsenic leached from the filters during the first 150 litres of filtration.

Based on the evidence presented in the IDE report mentioned above, it was assumed that the highest concentrations of arsenic would be detected in the first 50 litres of filtration. Therefore, five, 10-litre samples were taken during this filtration period (0-50 litres) against 20-litre samples for the following 100 litres (50-150 litres). The first litre of each of these 10-litre and 20-litre samples i.e. the 1st, 21st, 31st, 41st, 51st, 71st, 91st, 111th and 131st litre were collected separately, the arsenic concentration determined and then the 1-litre sample was returned to the sampling container where the larger 10-litre and 20-litre samples were collected. In this way, it was possible to investigate the arsenic concentration at key l-litre points as well as over the entire first 150 litres of filtration.

Analysis of the samples taken consecutively over the first 150 litres of filtration and the 1-litre samples revealed significant differences in the concentrations for each of the 46 filters tested. The figure below where the arsenic concentration of the first litre filtered was compared to the sample collected during the first 10 litres of operation predictably revealed the greatest differences.



The figure above reveals that the arsenic concentration of the 1st litre was higher than the average concentration over the first 10 litres for 85% of filters (39 of 46 filters). In fact, the arsenic concentration of the 1st litre was more than twice that of the first 10 litres for 65% of filters (30), more than 3 times the concentration for 52% (24 filters) and more than 5 times the concentration for 28% of filters (13 filters).

[1] Richard Tracey (2001), MSc Dissertation: "Low cost community water supply options for riverine communities in Stung Treng and Kratie provinces, Cambodia", Southampton University, UK

Similar yet less dramatic patterns were revealed for the other 10-litre and 20-litre samples indicating that the arsenic from the ceramic water filters is not released at a constant rate but released at unpredictable stages during operation. A full breakdown for each of the 46 filters tested over the total duration of the experiment is presented in Annex 11: *A comparison between the average Arsenic concentrations of 10-litre and 20-litre samples taken consecutively throughout the first 150 litres of filtration against 1-litre samples taken at key points.* However, it should be noted that the 46 filters presented in the 10 charts are NOT presented in the same order for each chart. The data is presented in order of the highest concentrations detected during each of the consecutive 10-litre and 20-litre samples. Consequently, it is not possible to use these charts to follow each filter individually.

To see in more detail that arsenic leached from each individual filter and to make comparisons by factory, the reader should refer to Annex 01 and Annex 02 where the numerical data is presented by filter. However, to further support the argument that leaching does not occur at a steadily reducing rate, data from 6 filters at one of the Twantay factories taken from these annexes is presented below

Table 1: Arsenic Concentration of 1-litre samples taken at key points during the first 150 litres of filtration

Factory	Arsenic concentration (ppb)									
	1st litre	11th litre	21st litre	31st litre	41st litre	51st litre	71st litre	91st litre	111th litre	131st litre
Factory 1	**121**	31	7	8	-	4	16	4	-	8
Factory 1	40	**120**	48	27	16	16	-	-	-	-
Factory 1	**92**	32	5	-	-	4	1	4	-	-
Factory 1	**111**	25	16	26	5	4	**96**	6	11	-
Factory 1	**106**	-	46	31	10	9	-		-	-
Factory 1	**82**	30	-	20	6	17	-	2	-	-

Table 2: Arsenic Concentration of samples taken consecutively throughout the first 150 litres of filtration

Factory	Arsenic Concentration (ppb)									
	0-10 litres	10-20 litres	20-30 litres	30-40 litres	40-50 litres	50-70 litres	70-90 litres	90-110 litres	110-130 litres	130-150 litres
Factory 1	31	13	19	1	5	14	-	7	-	-
Factory 1	34	27	5	14	1	17	8	-	-	-
Factory 1	28	3	-	-	-	4	-	-	-	-
Factory 1	10	31	1	10	17	-	11	5	-	-
Factory 1	**79**	17	5	3	16	-	-	-	-	-
Factory 1	8	17	-	12	8	-	-	-	-	-

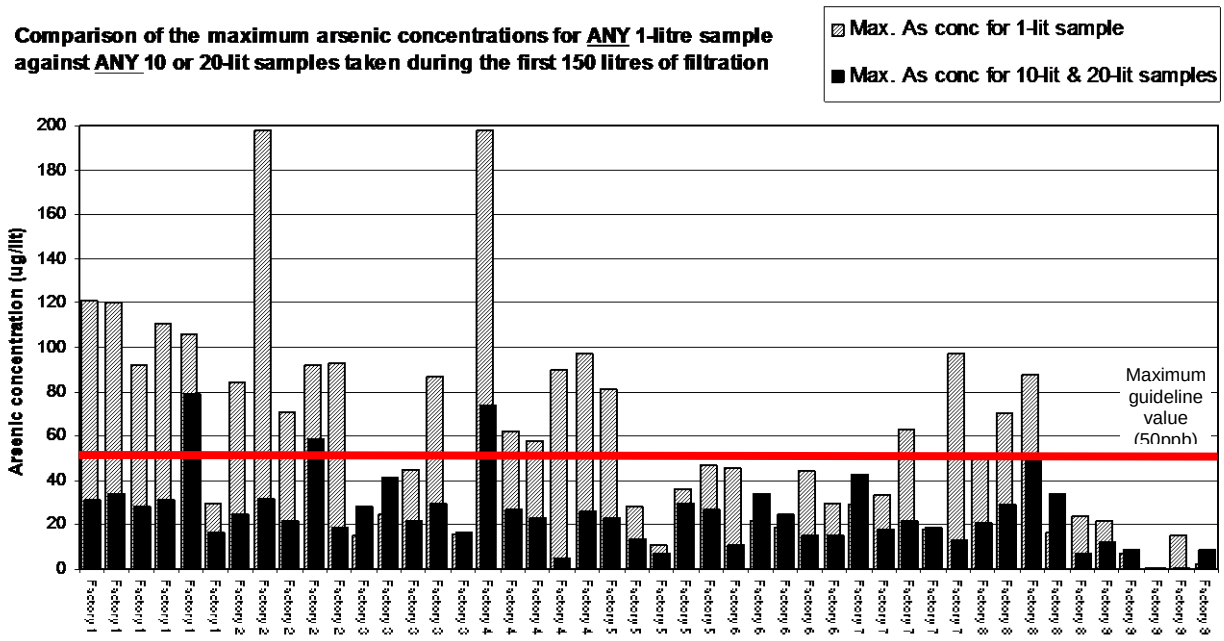
Legend *> 50 ppb* *10-50 ppb* *< 10 ppb*

The arsenic concentration detected at each stage in the first 150 litres of filtration does not follow a predictable pattern. Instead, concentrations rise and fall unpredictably throughout the first 100 litres of filtration after which time they taper off as arsenic concentrations become very low. When comparing the arsenic found in the 1st litre of the 10-litre and 20-litre samples, it was observed that sometimes almost all the arsenic is leached during the 1st litre of the sample while for other samples the 1st litre may contribute little to the arsenic contained in the larger sample.

B Maximum concentrations of Arsenic detected during the first 150 litres of filtration

The primary objective of this study was to determine whether the leaching of arsenic from ceramic water filters poses a health risk to users. Section A of the results and findings concludes that arsenic is not released from the filters at a steadily reducing rate and therefore the experiment may not detect the highest concentrations of arsenic released suddenly during the experiment. However, examination of the highest concentrations detected for both the single litre samples as well as the samples taken consecutively throughout the duration of the experiment provides an indication as to whether the leaching from ceramic water filters from the 9 factories poses a health risk or not.

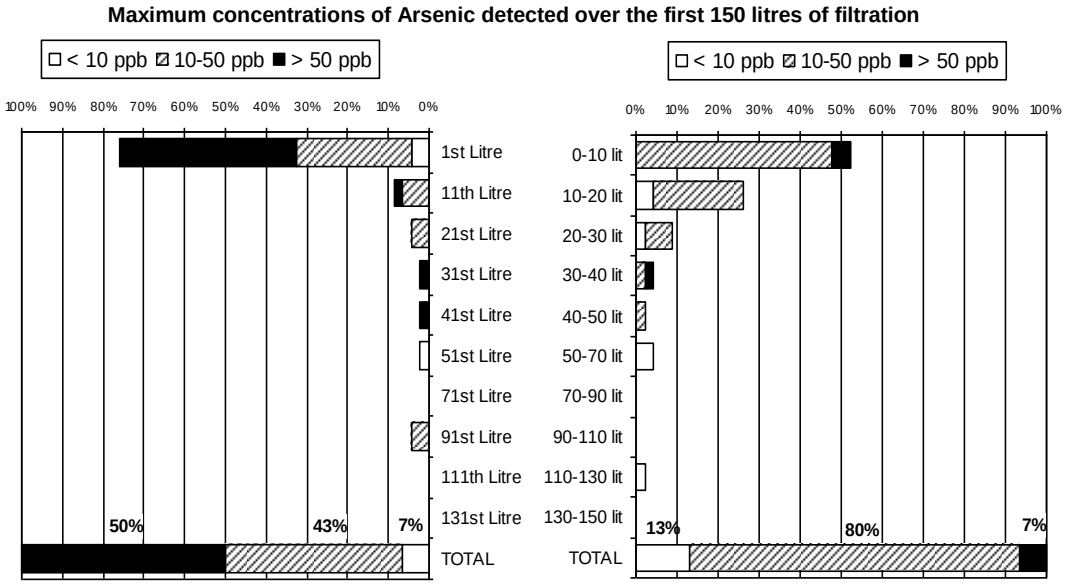
The figure below presents the maximum concentrations detected for any sample from a given filter.



While levels of arsenic leaching in excess of the maximum guideline value, commonly accepted in countries most affected by arsenic (50 ppb), was detected in 46% of the filters (21 filters) for at least one of the 1-litre samples, levels in excess of this guideline value were only detected in 7% of the filters (3 filters) for any of the 10-litre or 20-litre samples. These 3 filters originated from 3 different factories. The remaining 43 filters did not demonstrate levels in excess of the maximum guideline range for any of the samples taken consecutively throughout the first 150 litres of the experiment.

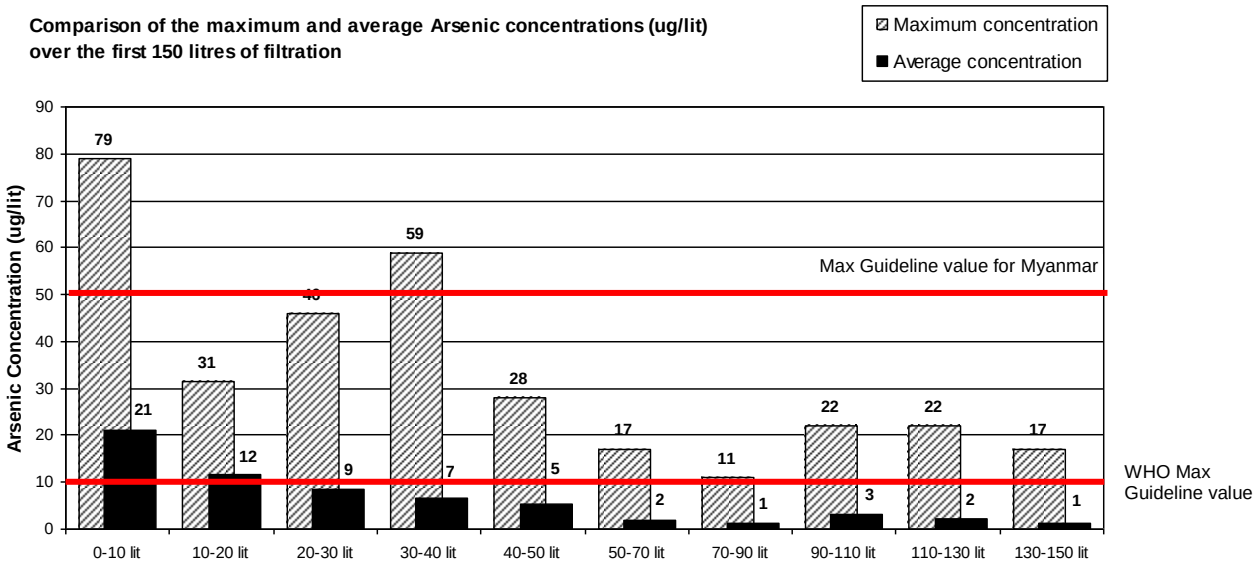
The highest concentrations of arsenic detected tended to be released in the very early stages of operation i.e. the first 10 litres of operation and the maximum concentrations detected for 1-litre samples occurred in the first litre of use for 76% of filters (36 of 46 filters). However, it must be noted that 1-litre samples were not taken between 1 and 9 litres of use and during this period, arsenic concentrations may have been higher in some filters as the arsenic does not leach at a steadily reducing rate. For the larger samples, 10-litre and 20-litre samples taken consecutively throughout the experiment, the highest arsenic concentrations were detected during the first 10-litres of operation (0-10 litres) for 52% of filters (24 of 46 filters).

The figure below illustrates at which point over the first 150 litres of filtration the highest levels of arsenic concentration were detected. As mentioned above, the first 10 litres of operation generally leached the highest concentrations of arsenic; 76% of filters for the single litre samples and 52% of filters for the 10-litre and 20-litre samples taken consecutively. The maximum concentrations were detected within the first 20-litres of operation for 78% of the samples taken consecutively and for 94% of filters within the first 50 litres of use. However, these maximum concentrations were only above the maximum WHO guideline value of 50ppb for 7% of filters (3 of 46 filters).



The maximum concentrations detected in the single litre samples appear to be of more concern; in the first litre of use the concentrations are above the WHO maximum guideline value of 50ppb for 43% of filters. However, it needs to be remembered the first 1-litre sample is included in the 0-10 litre sample and after dilution by filtered water of lower arsenic concentration, 90% of these contaminated samples reduced to acceptable levels; levels of contamination in excess of 50ppb was only detected in 2 filters for the 0-10 litre samples [4%] (see Annex 08 for more details).

As manufacturers and implementing agencies in Myanmar both recommend that users flush their filters out at least twice before domestic use, it is more relevant to look at the arsenic concentrations in the samples taken consecutively than the single litre samples. The figure below compares the maximum concentrations detected in any of the 46 filters against the average concentrations for the same filtration period in samples taken consecutively (see Annex 09 for more details).

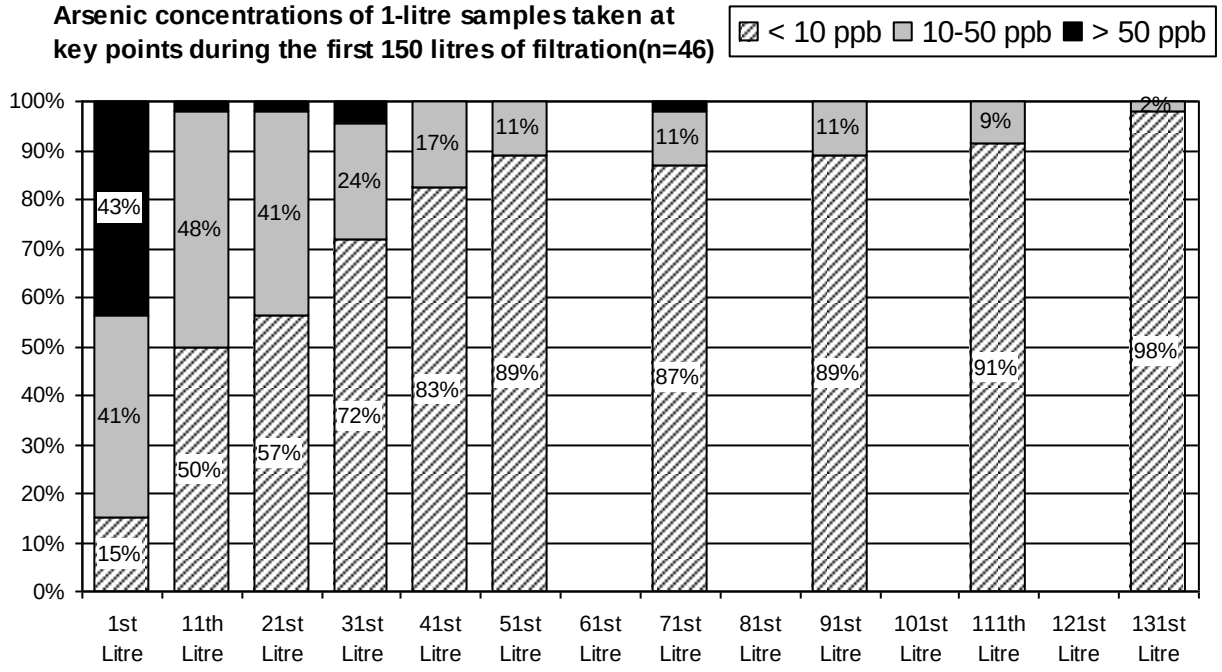


As the average concentrations of arsenic are far below the 50ppb guideline value and that levels above this were only detected once per filter for 3 different filters, it is highly unlikely that the ceramic water filters produced in Myanmar pose a health risk to users regarding exposure to arsenic.

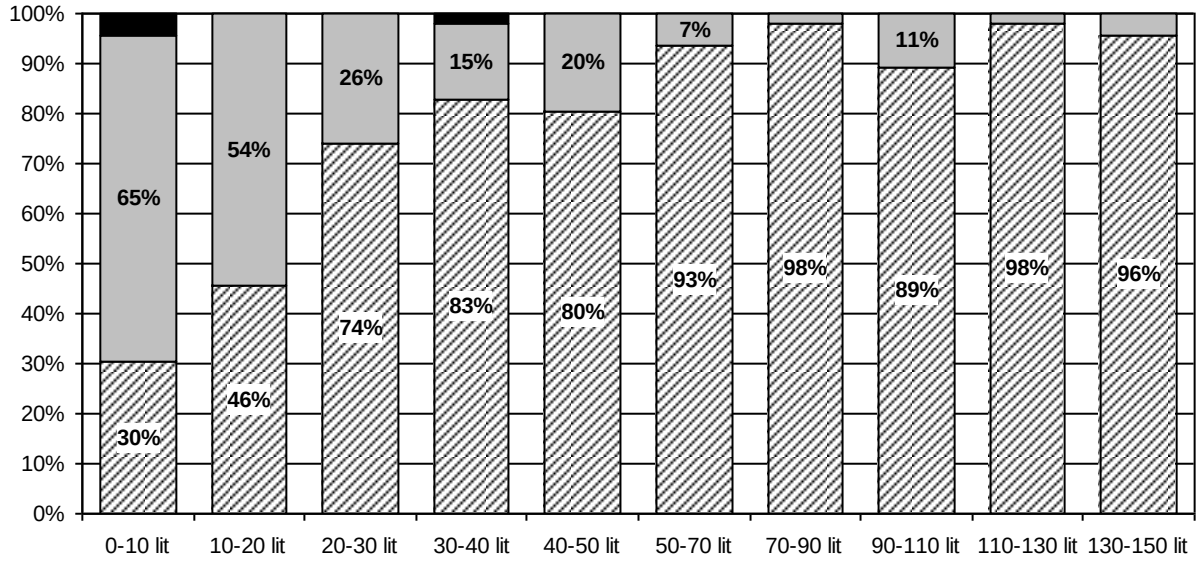
The figure above presents the maximum concentrations detected from any of the 46 filters against the average concentrations detected for all 46 of the filters. The two figures below present a breakdown by risk of exposure of the 46 filters for each of the samples taken during the experiment. As the primary objective of this study was to determine whether ceramic water filters manufactured in Myanmar pose a

health risk, the bars on the charts are colour-coded into 3 risk groups; 0-10ppb, 10-50ppb and > 50ppb (see Annex 06 and Annex 07 for more details).

Arsenic concentrations of 1-litre samples taken at key points during the first 150 litres of filtration(n=46)



Arsenic concentrations (ppb) detected during first 150 litres of flitration



As previously mentioned, the highest concentrations of arsenic were detected in the 1st litre of use with 43% of samples having concentrations in excess of the maximum guideline value for countries most affected by arsenic (50ppb) and 41% between 10ppb and 50ppb. However, comparisons of this single litre sample to the sample for the first 10 litres of operation reveals that concentrations reduce dramatically once the first litre is mixed with filtered water of lower concentrations i.e. the 2nd to 10th litres of operation. In the first 10-litres of use, only 4% of filters [2] produced samples above the 50ppb maximum guideline value while 65% of filters [30] produced filtered water of between 10ppb and 50ppb.

The two figures above present a similar pattern of reduction in arsenic concentrations with use. Over the first 50 litres, the average concentrations reduce to levels such that 80% of filters are producing filtered water below the WHO maximum guideline value of 10ppb. If the more appropriate maximum guideline

value of 50ppb is considered, 96% of filters constantly produced filtered water of acceptable arsenic concentrations and after 40 litres of use all filters produced acceptable levels for 10-litre samples. Consequently, it is highly unlikely that the water produced by ceramic water filters manufactured in Myanmar pose a significant health risk of arsenic exposure to users.

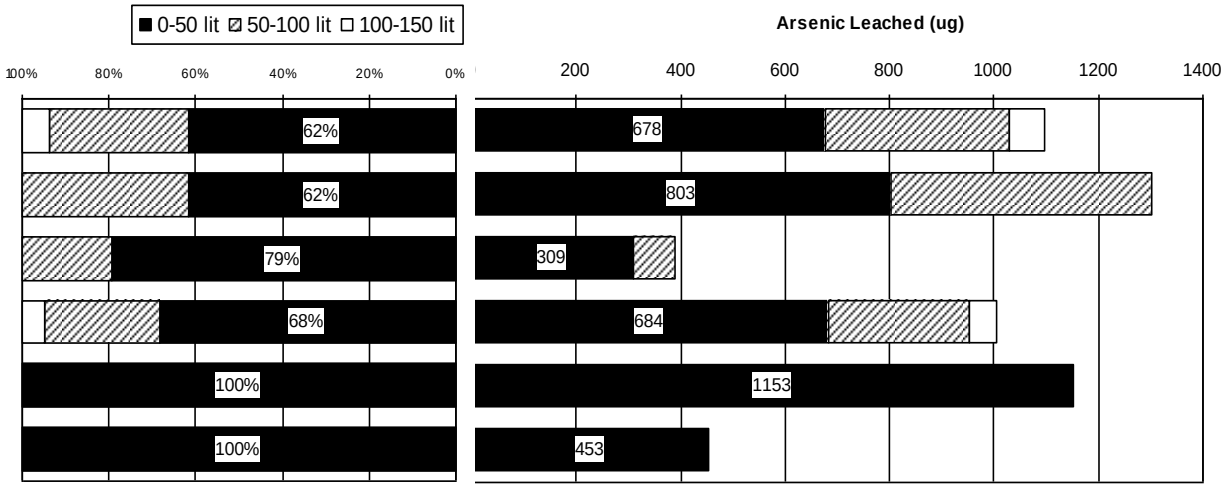
C Arsenic leached from 50-litre samples over the first 150 litres of use

Arsenic does not leach from ceramic filters at a steadily reducing rate. Instead, the filters tend to release arsenic spontaneously during use. However, the vast majority of the release tends to occur in the first 50 litres of filtration. The figure below illustrates the concentrations of arsenic detected over the first 3 consecutive 50-litres periods of filtration. In contrast to the section above where concentrations were measured for each 1-litre, 10-litre or 20-litre samples, these concentrations were calculated for the entire 50-litre sample.

When considering the entire 50-litre samples, arsenic concentrations in excess of the WHO maximum guideline value of 10ppb were detected in 41% of filters [19] while none of the filters operated in excess of the maximum guideline value accepted by countries most affected by arsenic (50ppb). Of the 19 filters with concentrations above 10ppb, 35% of all the filters produced filtered water of 10-20ppb, [16 of 46 filters], 4% [2 filters] produced filtered water of 20-30ppb and 2% [1 filter] produced filtered water of 30-40ppb.

The figure below is an extract from Annex 5: *Quantity of Arsenic leached in 50-litre samples over the first 150 hours of filtration* for the 6 filters tested from Factory 1 in Twantay. In this annex, the quantity of arsenic and the percentage of arsenic leached is presented for each of the three, 50-litre periods of filtration; 0-50 litres, 50-100 litres and 100-150 litres.

Total quantity of arsenic leached from filters from factory 1 by 50-litre samples



For a 50-litre sample, 500 micrograms (µg) of arsenic corresponds to a concentration of 10ppb while 2500 micrograms (µg) corresponds to a concentration of 50ppb. For all 46 filters tested in this experiment, all produced filtered water below 50ppb for 50-litre samples. For more details of the quantity of arsenic leached from each individual filter in 50-litre samples, see Annex 05 and Annex 10.

D Total quantity of arsenic leached over first 150 litres of filtration

A table of the cumulative quantity of arsenic (µg) leached from each individual filter is presented in Annex 04. An extract from this is presented below for 10 ceramic water filters (filters 6-15). In this table, the filters are not grouped by their factory of origin as with Annexes 01-03, instead they presented in a manner to illustrate how after 150 litres of use, 45 of the 46 filters tested produced filtered water below the WHO maximum guideline value of 10ppb. The table is therefore intended to give insight into how arsenic concentrations reduce with use.

Filter #	Total Arsenic leached from CWF during first 150 litres of use (µg)														
	0-10 litre	10-20 litre	20-30 litre	30-40 litre	40-50 litre	50-60 litre	60-70 litre	70-80 litre	80-90 litre	90-100 litre	100-110 litre	110-120 Litre	120-130 litre	130-140 litre	140-150 litre
6	**740**	**1010**	**1010**	**1070**	**1070**	**1070**	**1070**	**1070**	**1070**	**1070**	1070	1070	1070	1070	1070
7	**310**	**420**	**610**	**610**	**660**	**800**	**940**	**940**	**940**	**1010**	1080	1080	1080	1080	1080
8	**500**	**590**	**660**	**710**	**920**	**920**	**920**	**920**	**920**	920	920	920	920	920	920
9	**430**	**700**	**860**	**860**	**860**	**860**	**860**	**870**	**880**	880	880	910	940	940	940
10	**270**	**410**	**500**	**630**	**840**	**840**	**840**	**840**	**840**	**890**	940	940	940	940	940
11	**250**	**360**	**580**	**650**	**720**	**730**	**740**	740	740	740	740	790	840	840	840
12	**300**	**420**	**530**	**580**	**580**	**650**	**720**	760	800	830	860	890	920	1050	1180
13	**320**	**450**	**560**	**620**	**620**	**620**	620	650	680	680	680	680	680	680	680
14	**340**	**440**	**570**	**620**	**620**	**620**	620	620	620	620	620	620	620	620	620
15	**260**	**440**	**570**	**570**	**570**	570	570	570	570	570	570	570	570	580	590

Legend *> 50 ppb* *10-50 ppb* *< 10 ppb*

The figures in each cell are the cumulative quantity of arsenic in micrograms (µg) leached from each filter. In order to determine concentration, the total volume of filtered water was used i.e. for filter number 10, the total quantity of arsenic leached after 40 litres of filtration was 630µg (shown in red). The concentration of arsenic produced up until this point was therefore 630µg / 40 litres = 16ppb. As this concentration is between 10ppb and 50ppb the cell was shaded in grey.

Total Arsenic leached from CWF during first 150 litres of use (µg)														
0-10 litre	**10-20 litre**	**20-30 litre**	**30-40 litre**	**40-50 litre**	**50-60 litre**	**60-70 litre**	**70-80 litre**	**80-90 litre**	**90-100 litre**	**100-110 litre**	**110-120 Litre**	**120-130 litre**	**130-140 litre**	**140-150 litre**

Previous sections have examined how the arsenic concentrations leached from ceramic water filters manufactured Myanmar are not high enough to pose a significant health risk to users. In the table above, only the concentration ranges of each individual filter, 0-10ppb [white], 10-50pbb [grey] and >50ppb [black] is presented in order to highlight the trend in reducing arsenic concentrations over the first 150 litres of use. When considering the overall concentration of filtered water, concentrations of over 50ppb were only detected in 2 filters (4%). However, after 20 litres of use these levels had reduced to below the maximum guideline value of 50ppb.

The figure above reveals that arsenic concentrations reduce fairly quickly with use. After 50 litres, 27 of the 46 filters [59%] produced water with an average concentration of less than 10ppb while the remaining 19 filters [41%] produced filtered water of between 10ppb and 50ppb. However, this is regarded as the worst case scenario and as both manufacturers and implementing agencies recommend the first 20 litres of filtered water is discarded, primarily for reasons of taste and user acceptance of the technology. Therefore, it is worth repeating the exercise without considering the first 20 litres of filtration. The table below illustrates the difference in the concentrations of water more likely to be consumed by users.

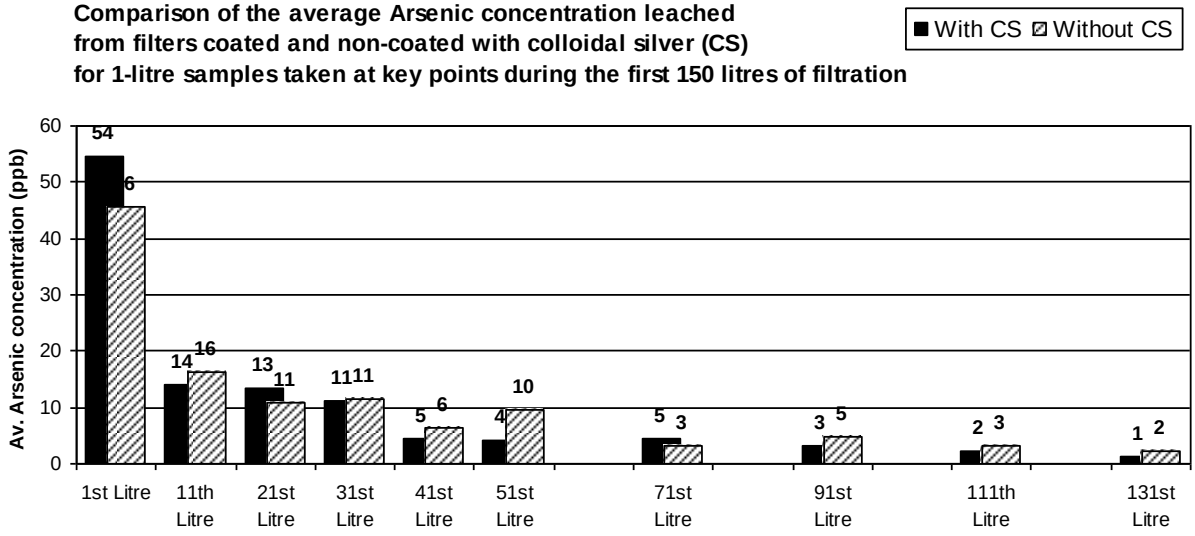
Total Arsenic leached from CWF during first 150 litres of use (µg)														
0-10 litre	**10-20 litre**	**20-30 litre**	**30-40 litre**	**40-50 litre**	**50-60 litre**	**60-70 litre**	**70-80 litre**	**80-90 litre**	**90-100 litre**	**100-110 litre**	**110-120 Litre**	**120-130 litre**	**130-140 litre**	**140-150 litre**
First 20 liters of Filtration discarded		460	1050	1220	**1220**	1220	**1220**	1220	**1250**	1280	**1280**	1280	**1450**	1620
		50	170	270	**440**	610	**610**	610	**610**	610	**660**	710	**710**	710
		50	190	190	**360**	530	**610**	690	**690**	690	**690**	690	**690**	690
		290	340	550	**550**	550	**550**	550	**720**	890	**920**	950	**950**	950
		190	190	240	**380**	520	**520**	520	**590**	660	**660**	660	**660**	660
		90	220	430	**430**	430	**430**	430	**480**	530	**530**	530	**530**	530
		220	290	360	**370**	380	**380**	380	**380**	380	**430**	480	**480**	480
		300	300	330	**380**	430	**430**	430	**430**	430	**440**	450	**450**	450
		70	120	330	**330**	330	**330**	330	**330**	330	**330**	330	**330**	330
		20	50	330	**330**	330	**330**	330	**330**	330	**550**	770	**820**	870
		230	230	230	**230**	230	**230**	230	**230**	230	**230**	230	**260**	290
		70	290	290	**340**	390	**440**	490	**630**	770	**790**	810	**810**	810
		90	220	220	**220**	220	**220**	220	**290**	360	**410**	460	**470**	480
		50	210	210	**210**	210	**290**	370	**370**	370	**400**	430	**430**	430
		160	160	160	**160**	160	**170**	180	**180**	180	**210**	240	**240**	240
		110	160	160	**230**	300	**340**	380	**410**	440	**470**	500	**630**	760
		130	130	130	**130**	130	**130**	130	**130**	130	**130**	130	**140**	150
		130	180	180	**180**	180	**180**	180	**180**	180	**180**	180	**180**	180
		130	180	240	**240**	240	**240**	240	**300**	360	**360**	360	**360**	360
		110	170	170	**170**	170	**200**	230	**230**	230	**230**	230	**230**	230
		0	0	0	**40**	80	**80**	80	**80**	80	**80**	80	**80**	80
		0	100	270	**270**	270	**380**	490	**540**	590	**590**	590	**590**	590
		0	30	190	**190**	190	**190**	190	**190**	190	**190**	190	**190**	190
		0	120	200	**200**	200	**200**	200	**200**	200	**200**	200	**200**	200
		60	60	120	**120**	120	**120**	120	**120**	120	**150**	180	**180**	180
		0	30	30	**70**	110	**110**	110	**330**	550	**550**	550	**550**	550
		0	0	0	**0**	0	**50**	100	**100**	100	**100**	100	**100**	100
		0	60	60	**60**	60	**60**	60	**60**	60	**60**	60	**60**	60
		30	30	100	**100**	100	**100**	100	**100**	100	**100**	100	**100**	100
		20	70	70	**70**	70	**110**	150	**150**	150	**150**	150	**150**	150
		50	50	50	**50**	50	**50**	50	**50**	50	**50**	50	**50**	50
		0	0	0	**0**	0	**0**	0	**0**	0	**0**	0	**0**	0
		70	70	70	**70**	70	**70**	70	**70**	70	**70**	70	**70**	70
		60	60	60	**60**	60	**60**	60	**60**	60	**60**	60	**60**	60
		0	30	30	**30**	30	**60**	90	**90**	90	**90**	90	**90**	90
		0	0	30	**30**	30	**30**	30	**80**	130	**130**	130	**130**	130
		90	130	130	**170**	210	**310**	410	**520**	630	**630**	630	**630**	630
		20	20	20	**20**	20	**20**	20	**150**	280	**310**	340	**340**	340
		0	10	120	**180**	240	**240**	240	**240**	240	**240**	240	**240**	240
		0	0	150	**150**	150	**150**	150	**150**	150	**150**	150	**150**	150
		0	60	60	**110**	160	**160**	160	**160**	160	**160**	160	**160**	160
		80	130	130	**130**	130	**130**	130	**130**	130	**140**	150	**150**	150
		0	30	30	**30**	30	**50**	70	**100**	130	**220**	310	**320**	330
		0	0	0	**10**	20	**30**	40	**40**	40	**40**	40	**40**	40
		0	0	0	**10**	20	**20**	20	**30**	40	**40**	40	**40**	40
		50	50	50	**100**	150	**150**	150	**150**	150	**150**	150	**150**	150

Legend *> 50 ppb* *10-50 ppb* *< 10 ppb*

When the first 20-litres of filtration is discarded, the number of filters operating at below the WHO maximum guideline value of 10ppb from the outset, increases from 20% to 57% of filters while 41% of the filters operate at levels between 10ppb and 50ppb. Only one filter was found to be producing filtered water above the 50ppb guideline value. After 60-litres of filtered water, likely to be consumed by users, only one filter produced filtered water above the WHO maximum guideline value of 10ppb at 20ppb.

E Does colloidal silver play a significant role in the leaching of arsenic from ceramic water filters ?

It had been suggested that the colloidal silver painted onto the ceramic water filters to kill harmful pathogens may play a significant role in arsenic leaching. To investigate this, the experiment was conducted in the same manner for 10 ceramic water filters that had not been coated in colloidal silver.



The figure above presents the average arsenic concentrations taken at key points during the experiment. As the differences are only slight, it would appear that the colloidal silver does not play a significant role in promoting the leaching of arsenic from ceramic water filters.

F The effective of soaking ceramic water filters prior to use/sale in reducing arsenic leaching

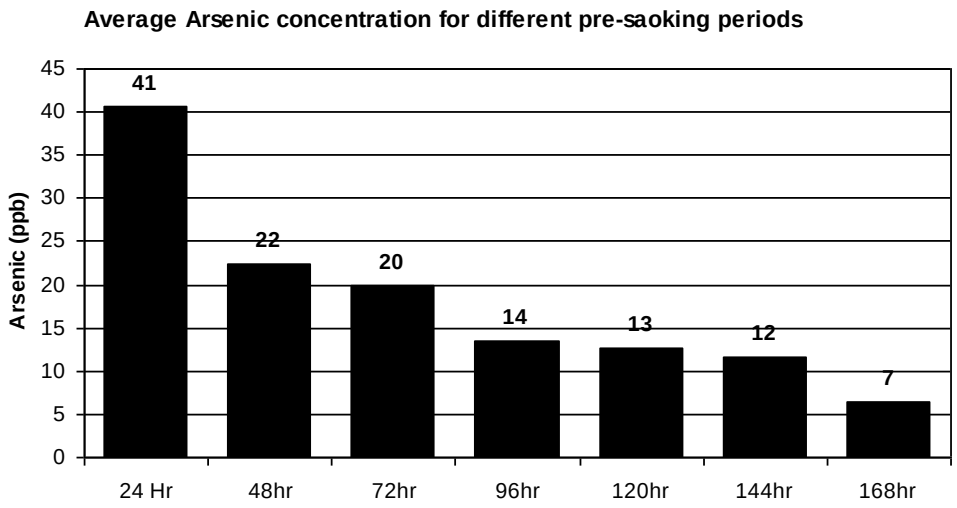
The report by International Development Enterprises (IDE) on arsenic leaching from ceramic water filters produced in Cambodia concluded that pre-soaking filters for 72 hours would prevent further arsenic leaching. To investigate this claim and see if it was applicable to filters manufactured in Myanmar, a sample of 18 filters, 2 from each of the Myanmar factories, were completely submerged in water for 24 hours and then operated for 1 hour. The average concentration of this 1-hour sample was then determined and the filters returned to the water to soak for a further 24 hours before repeating the process. Each of the filters was soaked for a total of 7 days (168 hours) and the concentrations of 1-hour samples were tested for arsenic. The table below presents the findings of the experiment.

Factory name	Arsenic Concentration for 1st hour of filtration						
	24 Hr	48 Hr	72hr	96 hr	120 hr	144 hr	168 hr
Factory 1	63	45	11	27	31	16	8
	87	47	77	31	46	39	21
Factory 2	98	41	39	38	23	25	20
	44	43	30	26	21	40	15
Factory 3	55	38	29	0	17	21	13
	28	16	36	16	4	3	8
Factory 4	87	48	19	17	5	9	3
	93	36	22	19	23	7	12
Factory 5	7	6	0	4	11	6	2
	16	0	12	0	0	0	0
Factory 6	10	3	0	7	0	6	3
	45	18	3	6	4	0	3
Factory 7	45	27	27	24	24	13	0
	22	15	0	14	9	11	5
Factory 8	8	12	7	10	7	10	2
	13	0	0	4	0	1	0
Factory 9	11	7	38	0	0	1	2
	0	0	9	0	3	2	0
Average	41	22	20	14	13	12	7

Legend *> 50 ppb* *10-50 ppb* *< 10 ppb*

If the average 1st-hour flow rate is assumed to be 2.5 litres per hour, it needs to be remembered that in addition to 6-days of soaking under water, each of the 18 filters tested were operated for approximately 17.5 litres of filtration. Thus, as discussed in previous sections, the highest concentrations of arsenic tend to be leached during this period of use and levels would be expected to be high.

The figure below presents the average concentrations of arsenic leached from the 18 filters over the 6-day soaking period.



It was observed that the average arsenic concentrations leached from the filters reduced steadily over the 6-day period. However, the reduction was not significant enough to justify the claim made by IDE that 72 hours of soaking will prevent arsenic leaching from ceramic water filters. Consequently, rather than advise manufacturers to soak the filters for additional periods before sale, as mentioned in section D, it is wiser to recommend users to flush their new ceramic water filters through twice before domestic use.

G The origin of the Arsenic leached from ceramic water filters

It was intention of this study to determine the origin of the arsenic leached from ceramic water filters manufactured in Myanmar. Each of the 9 ceramic water filter factories provided samples of the clays used to the make the filters provided for the experiment as well as the rice husks, or the sawdust, used to create the porosity of the filters.

To determine the arsenic content of the clays, rice husks and sawdust, it is necessary to use an atomic absorption spectrometer, the likes of which are only available in Myanmar at key government institutions. However, during the course of this study, the Myanmar government changed the regulations concerning the use of this equipment and to gain access to it now requires permission at central government level in Nay Pyi Daw. Unfortunately, it was not possible to obtain this permission during the timeframe of this study and consequently, it was not possible to determine the origin of the arsenic leached from the filters. However, as this study does not regard the leaching from arsenic as a significant health risk, the origin of the arsenic is no longer as important as was first thought.

Conclusion

Based on the evidence presented in this study, the consultant does not regard the risk of arsenic exposure from the leaching of ceramic water filters to be a significant health risk to users. The study confirms the observations published by both ICRC (2006) and Oxfam (2009) stating that significantly high levels of arsenic are released by ceramic water filters in the first stages of use. However, the highest concentrations observed were 200ppb for 2 single litre samples from 2 of the 46 filters [4%]. Once these samples were mixed with filtered water from the next few litres of use, the overall arsenic concentration reduced to levels below the maximum guideline value for countries most affected by arsenic of 50ppb. These usually high concentrations of arsenic tended to be released during the first 20-litres of operation. Consequently, if the first 20-litres of filtered water is discarded before the filters are commissioned for household consumption, as recommended by both manufacturers and implementing agencies, the risk of exposure dramatically reduces to acceptable levels.

It was not possible during this study to determine the origin of the arsenic. However, in the consultant's opinion, the majority of the arsenic is highly likely to originate from the rice husks used to create the porosity in the filters based on tests conducted by Community Development Association (CDA) in Yangon.

The study was able to conclude two additional findings, that the leaching of arsenic does not appear related to the colloidal silver coating painted on ceramic water filter to kill harmful pathogens and that the theory, suggested by International Development Enterprises (IDE), Cambodia, that arsenic leaching could be prevented by soaking the filters under water for 72 hours does not appear to apply to filters manufactured in Myanmar. Soaking the filters over a 168-hour period had little additional effect on reducing the leaching that would normally be observed in the first 20-litres of use.

ANNEXES

Annex 01: Arsenic concentrations for single litre samples taken during first 150 litres of use

Annex 02: Arsenic concentrations for 10-litres samples (0-50 lit) and 20-litre samples (50-150 lit) taken during the first 150 litres of filtration

Annex 03: Quantity of Arsenic (µg) leached from CWF during the first 150 litres of use

Annex 04: Cumulative quantity of Arsenic leached from CWF during first 150 litres of use (µg/lit)

Annex 05: Quantity of Arsenic leached over the first 150 hours of filtration

Annex 06: Average Arsenic concentration of 1-litre samples taken at key points over the first 150 litres of use

Annex 07: Av. Arsenic concentration of samples taken over the first 150 litres of use

Annex 08: Maximum Arsenic concentrations detected from 46 filters during the first 150 litres of filtration

Annex 09: Comparison between the maximum and average arsenic concentrations detected for samples taken consecutively over the first 150 litres of filtration

Annex 10 Total Arsenic leached over 50 litres, 100 litres and 150 litres of filtration

Annex 11: Comparison between the Average Arsenic concentrations of 10-litre and 20-litre samples taken continuously through the first 150 of filtration against 1-litre samples taken at key points (n=46)

Note to the Annexes:

Annex 01-04

To assist the interpretation of the numerical data presented in annexes 01-04, a colour-coding system was used to highlight significant arsenic concentrations

> 50 ppb

10-50 ppb

< 10 ppb

Annex 01: Arsenic concentrations for single litre samples taken during first 150 litres of use

Factory	Arsenic concentration (µg/lit)									
	1st liter	11th Litre	21st Litre	31st Litre	41st Litre	51st Litre	71st Litre	91st Litre	111th Litre	131st Litre
Factory 1	121	31	7	8	-	4	16	4	-	8
Factory 1	40	120	48	27	16	16	-	-	-	-
Factory 1	92	32	5	-	-	4	1	4	-	-
Factory 1	111	25	16	26	5	4	96	6	11	-
Factory 1	106	-	46	31	10	9	-		-	-
Factory 1	82	30	-	20	6	17	-	2	-	-
Factory 2	84	-	47	5	12	2	13	1	-	-
Factory 2	198	10	19	18	13	27	-	6	-	5
Factory 2	71	13	20	-	-	-	-	7	-	5
Factory 2	92	16	26	77	11	6	-	2	4	-
Factory 2	93	24	92	36	13	-	-	5	-	4
Factory 3	11	-	10	6	-	-	-	15	-	3
Factory 3	25	-	16	6	5	-	-		8	-
Factory 3	45	7	4	-	-	-	10	15	-	-
Factory 3	87	17	9	-	4	6	10	2	2	-
Factory 3	5	16	10	-	-	7	-	11	6	-
Factory 4	198	19	11	2	-	5	6	-	11	1
Factory 4	62	12	24	14	-	-	-	-	-	-
Factory 4	58	13	14	6	35	-	-	-	-	-
Factory 4	90	10	-	8	-	-	-	-	3	-
Factory 4	97	9	-	3	-	-	-	-	-	-
Factory 5	22	6	-	81	-	-	-	-	-	-
Factory 5	28	10	10	6	-	3	-	¢	4	-
Factory 5	8	-	11	-	-	-	-	-	-	3
Factory 5	36	8	7	16	-	6	-	-	3	-
Factory 5	47	14	6	18	17	18	6	-	4	5
Factory 6	46	-	-	24	-	7	-	-	-	-
Factory 6	22	18	6	7	-	-	-	-	-	3
Factory 6	16	19	19	-	-	-	-	-	-	-
Factory 6	44	30	4	-	-	-	-	6	-	3
Factory 6	30	14	25	-	-	-	-	5	-	-
Factory 7	7	14	29	3	-	13	7	-	-	4
Factory 7	33	24	4	-	-	9	-	6	11	-
Factory 7	63	-	20	7	-	-	4	14	16	-
Factory 7	18	3	-	-	-	-	3	-	5	11
Factory 7	97	13	11	6	-	4	11	7	6	-
Factory 8	30	7	10	-	50	-	13	-	-	-
Factory 8	70	34	13	49	-	-	-	-	-	-
Factory 8	88	-	-	-	-	8	3	-	-	-
Factory 8	-	-	-	5	8	-	-	17	-	-
Factory 8	14	24	17	-	-	-	-	-	-	-
Factory 9	22	5	-	-	-	10	11	-	1	-
Factory 9	7	-	-	4	1	-	1	1	1	-
Factory 9	1	-	-	-	-	-	-	1	-	-
Factory 9	15	-	-	1	1	-	-	5	3	-
Factory 9	-	-	-	-	1	¢	1	-	-	-
Average	**54**	**14**	**13**	**11**	**5**	**4**	**5**	**3**	**2**	**1**

Annex 02: Arsenic concentrations for 10-litres samples (0-50 lit) and 20-litre samples (50-150 lit) taken during the first 150 litres of filtration

Factory	Arsenic Concentration (µg/lit)									
	0-10 litres	10-20 litres	20-30 litres	30-40 litres	40-50 litres	50-70 litres	70-90 litres	90-110 litres	110-130 litres	130-150 litres
Factory 1	31	13	19	-	5	14	-	7	-	-
Factory 1	34	27	5	14	-	17	8	-	-	-
Factory 1	28	3	-	-	-	4	-	-	-	-
Factory 1	10	31	-	10	17	-	11	5	-	-
Factory 1	79	17	-	3	16	-	-	-	-	-
Factory 1	8	17	-	12	8	-	-	-	-	-
Factory 2	25	11	22	7	7	1	-	-	5	-
Factory 2	32	13	11	6	-	-	3	-	-	-
Factory 2	12	22	6	-	6	-	-	-	3	-
Factory 2	26	30	46	59	17	-	-	3	-	17
Factory 2	19	19	5	16	-	-	8	-	3	-
Factory 3	15	5	2	3	28	-	-	-	22	5
Factory 3	41	14	5	12	10	17	-	-	5	-
Factory 3	22	8	-	3	-	4	-	22	-	-
Factory 3	30	12	11	5	-	7	4	3	3	13
Factory 3	6	17	-	-	-	-	5	-	-	-
Factory 4	74	27	-	6	-	-	-	-	-	-
Factory 4	27	11	3	-	7	-	-	-	-	-
Factory 4	23	13	¢	5	-	-	4	-	-	-
Factory 4	4	5	5	-	-	-	-	-	-	-
Factory 4	26	18	13	-	-	-	-	-	-	1
Factory 5	15	-	23	-	-	-	-	-	-	3
Factory 5	14	6	-	-	-	-	-	-	-	-
Factory 5	-	2	7	-	-	-	-	-	-	-
Factory 5	9	11	30	-	3	5	-	-	1	-
Factory 5	27	14	9	13	21	-	-	5	-	-
Factory 6	11	3	6	-	-	-	-	-	-	-
Factory 6	34	10	13	5	-	-	-	-	-	-
Factory 6	3	25	-	3	-	-	3	-	-	-
Factory 6	11	15	13	5	6	-	-	6	-	-
Factory 6	12	15	-	-	3	-	-	5	-	-
Factory 7	43	27	16	-	-	-	1	-	3	-
Factory 7	18	3	9	4	-	4	10	11	-	-
Factory 7	1	3	7	22	-	5	5	14	¢	-
Factory 7	1	19	2	-	-	-	-	13	3	-
Factory 7	13	5	9	13	-	-	-	7	5	1
Factory 8	21	-	-	1	11	6	-	-	-	-
Factory 8	23	20	29	5	21	-	-	17	3	-
Factory 8	50	9	7	5	21	-	-	-	-	-
Factory 8	34	-	-	-	15	-	-	-	-	-
Factory 8	3	7	-	6	-	5	-	-	-	-
Factory 9	12	1	8	5	-	-	-	-	1	-
Factory 9	-	-	-	3	-	-	2	3	9	1
Factory 9	-	-	-	-	-	1	1	-	-	-
Factory 9	-	-	-	-	-	1	-	1	-	-
Factory 9	-	9	5	-	-	5	-	-	-	-
Average	20	12	8	5	5	2	1	3	1	1

Annex 03: Quantity of Arsenic (µg) leached from CWF during the first 150 litres of use

Factory	Arsenic leached from CWF during first 150 litres of use (ug)										TOTAL Arsenic (µg)	Average Arsenic concentration (µg/lit)
	0-10 litres	10-20 litres	20-30 litres	30-40 litres	40-50 litres	50-70 litres	70-90 litres	90-110 litres	110-130 litres	130-150 litres		
Factory 1	310	128	179	-	50	280	-	140	-	-	1087	7
Factory 1	340	273	89	140	-	340	160	-	-	-	1342	9
Factory 1	280	29	5	-	-	80	-	-	-	-	394	3
Factory 1	100	314	15	100	170	-	220	100	-	-	1018	7
Factory 1	790	173	42	30	160	-	-	-	-	-	1195	8
Factory 1	80	173	-	120	80	-	-	-	-	-	453	3
Factory 2	250	110	220	70	70	20	-	-	100	-	840	6
Factory 2	320	130	110	60	-	-	60	-	-	-	680	5
Factory 2	120	220	60	-	60	-	-	-	60	-	520	3
Factory 2	260	300	460	590	170	-	-	60	-	340	2180	15
Factory 2	190	190	50	160	-	-	160	-	60	-	810	5
Factory 3	150	50	20	30	280	-	-	-	440	100	1070	7
Factory 3	410	140	50	120	100	340	-	-	100	-	1260	8
Factory 3	220	80	-	30	-	80	-	440	-	-	850	6
Factory 3	300	120	110	50	-	140	80	60	60	260	1180	8
Factory 3	60	170	-	-	-	-	100	-	-	-	330	2
Factory 4	740	270	-	60	-	-	-	-	-	-	1070	7
Factory 4	270	110	30	-	70	-	-	-	-	-	480	3
Factory 4	230	130	20	50	-	-	80	-	-	-	510	3
Factory 4	40	50	50	-	-	-	-	-	-	-	140	1
Factory 4	260	180	130	-	-	-	-	-	-	20	590	4
Factory 5	150	-	230	-	-	-	-	-	-	60	440	3
Factory 5	140	60	-	-	-	-	-	-	-	-	200	1
Factory 5	-	20	70	-	-	-	-	-	-	-	90	1
Factory 5	90	110	300	-	30	100	-	-	20	-	650	4
Factory 5	270	140	90	130	210	-	-	100	-	-	940	6
Factory 6	110	30	60	-	-	-	-	-	-	-	200	1
Factory 6	340	100	130	50	-	-	-	-	-	-	620	4
Factory 6	30	250	-	30	-	-	60	-	-	-	370	2
Factory 6	110	150	130	50	60	-	-	120	-	-	620	4
Factory 6	120	150	-	-	30	-	-	100	-	-	400	3
Factory 7	430	270	160	-	-	-	20	-	60	-	940	6
Factory 7	180	30	90	40	-	80	200	220	-	-	840	6
Factory 7	10	30	70	220	-	100	100	280	40	-	850	6
Factory 7	10	190	20	-	-	-	-	260	60	-	540	4
Factory 7	130	50	90	130	-	-	-	140	100	20	660	4
Factory 8	210	-	-	10	110	120	-	-	-	-	450	3
Factory 8	230	200	290	50	210	-	-	340	60	-	1380	9
Factory 8	500	90	70	50	210	-	-	-	-	-	920	6
Factory 8	340	-	-	-	150	-	-	-	-	-	490	3
Factory 8	30	70	-	60	-	100	-	-	-	-	260	2
Factory 9	120	10	80	50	-	-	-	-	20	-	280	2
Factory 9	-	-	-	30	-	-	40	60	180	20	330	2
Factory 9	-	-	-	-	-	20	20	-	-	-	40	1
Factory 9	-	-	-	-	-	20	-	20	-	-	40	1
Factory 9	-	90	50	-	-	100	-	-	-	-	240	2
Average	**202**	**117**	**78**	**55**	**48**	**42**	**28**	**53**	**30**	**18**	**669**	**4**

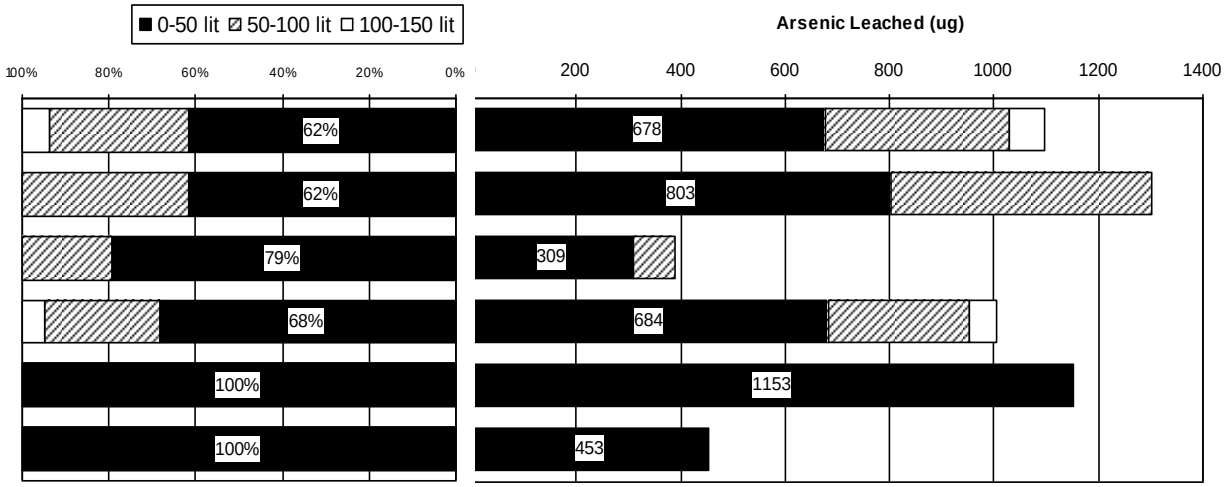
Annex 04: Cumulative quantity of Arsenic leached from CWF during first 150 litres of use (µg)

Filter #	Total Arsenic leached from CWF during first 150 litres of use (µg/lit)														
	0-10 litre	10-20 litre	20-30 litre	30-40 litre	40-50 litre	50-60 litre	60-70 litre	70-80 litre	80-90 litre	90-100 litre	100-110 litre	110-120 litre	120-130 litre	130-140 litre	140-150 litre
1	260	560	1020	1610	1780	1780	1780	1780	1780	1810	1840	1840	1840	2010	2180
2	230	430	720	770	980	980	980	980	980	1150	1320	1350	1380	1380	1380
3	410	550	600	720	820	990	1160	1160	1160	1160	1160	1210	1260	1260	1260
4	340	520	570	710	710	880	1050	1130	1210	1210	1210	1210	1210	1210	1210
5	790	980	980	1010	1170	1170	1170	1170	1170	1170	1170	1170	1170	1170	1170
6	740	1010	1010	1070	1070	1070	1070	1070	1070	1070	1070	1070	1070	1070	1070
7	310	420	610	610	660	800	940	940	940	1010	1080	1080	1080	1080	1080
8	500	590	660	710	920	920	920	920	920	920	920	920	920	920	920
9	430	700	860	860	860	860	860	870	880	880	880	910	940	940	940
10	270	410	500	630	840	840	840	840	840	890	940	940	940	940	940
11	250	360	580	650	720	730	740	740	740	740	740	790	840	840	840
12	300	420	530	580	580	650	720	760	800	830	860	890	920	1050	1180
13	320	450	560	620	620	620	620	650	680	680	680	680	680	680	680
14	340	440	570	620	620	620	620	620	620	620	620	620	620	620	620
15	100	420	420	520	690	690	690	800	910	960	1010	1010	1010	1010	1010
16	260	440	570	570	570	570	570	570	570	570	570	570	570	580	590
17	190	380	430	590	590	590	590	670	750	750	750	780	810	810	810
18	150	200	220	250	530	530	530	530	530	530	530	750	970	1020	1070
19	90	200	500	500	530	580	630	630	630	630	630	640	650	650	650
20	110	260	390	440	500	500	500	500	500	560	620	620	620	620	620
21	230	360	380	430	430	430	430	470	510	510	510	510	510	510	510
22	270	380	410	410	480	480	480	480	480	480	480	480	480	480	480
23	120	340	400	400	460	460	460	460	460	460	460	490	520	520	520
24	150	150	380	380	380	380	380	380	380	380	380	380	380	410	440
25	340	340	340	340	490	490	490	490	490	490	490	490	490	490	490
26	220	300	300	330	330	370	410	410	410	630	850	850	850	850	850
27	30	280	280	310	310	310	310	340	370	370	370	370	370	370	370
28	120	270	270	270	300	300	300	300	300	350	400	400	400	400	400
29	60	230	230	230	230	230	230	280	330	330	330	330	330	330	330
30	180	210	300	340	340	380	420	520	620	730	840	840	840	840	840
31	210	210	210	220	330	390	450	450	450	450	450	450	450	450	450
32	280	280	280	280	280	320	360	360	360	360	360	360	360	360	360
33	80	240	240	360	440	440	440	440	440	440	440	440	440	440	440
34	140	200	200	200	200	200	200	200	200	200	200	200	200	200	200
35	130	180	270	400	400	400	400	400	400	470	540	590	640	650	660
36	120	130	210	260	260	260	260	260	260	260	260	270	280	280	280
37	110	140	200	200	200	200	200	200	200	200	200	200	200	200	200
38	40	90	140	140	140	140	140	140	140	140	140	140	140	140	140
39	30	100	100	160	160	210	260	260	260	260	260	260	260	260	260
40	10	40	110	330	330	380	430	480	530	670	810	830	850	850	850
41	10	200	220	220	220	220	220	220	220	350	480	510	540	540	540
42	0	20	90	90	90	90	90	90	90	90	90	90	90	90	90
43	0	0	0	30	30	30	30	50	70	100	130	220	310	320	330
44	0	0	0	0	0	10	20	30	40	40	40	40	40	40	40
45	0	0	0	0	0	10	20	20	20	30	40	40	40	40	40
46	0	90	140	140	140	190	240	240	240	240	240	240	240	240	240

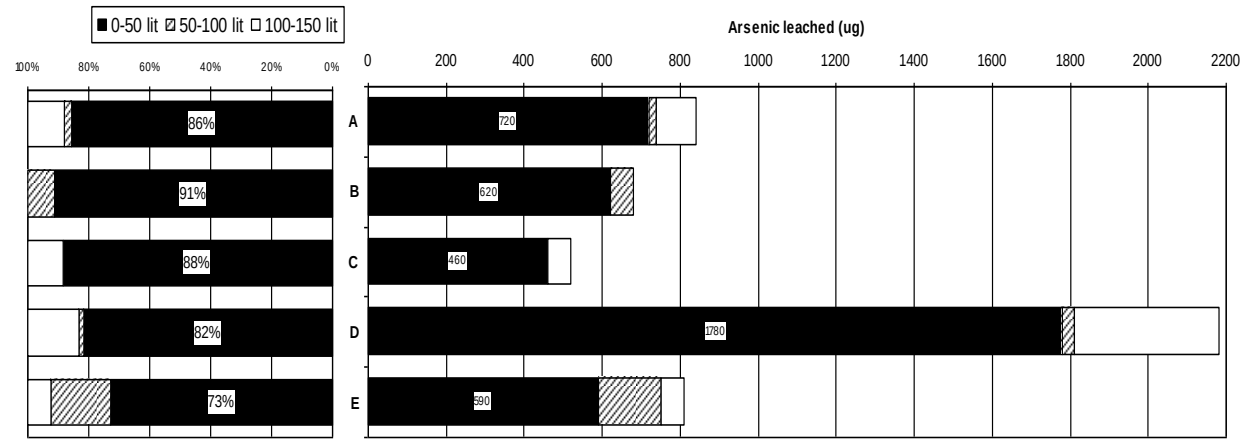
Legend *> 50 ppb* *10-50 ppb* *< 10 ppb*

Annex 05: Quantity of Arsenic leached in 50-litre samples over the first 150 hours of filtration by factory and by individual filter (n=46)

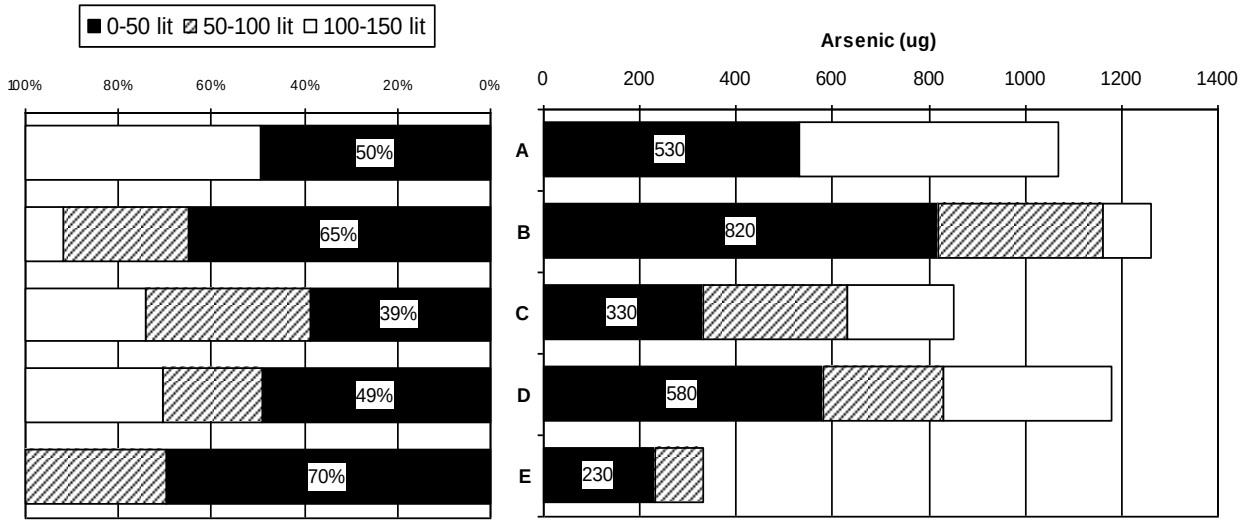
Factory 1 (6 filters)



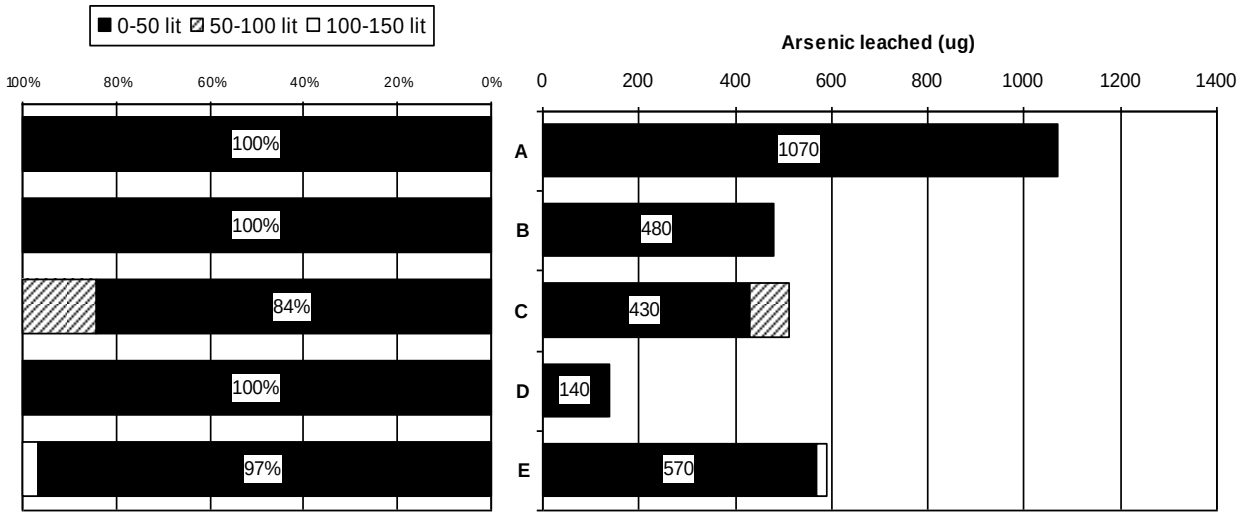
Factory 2 (5 filters)



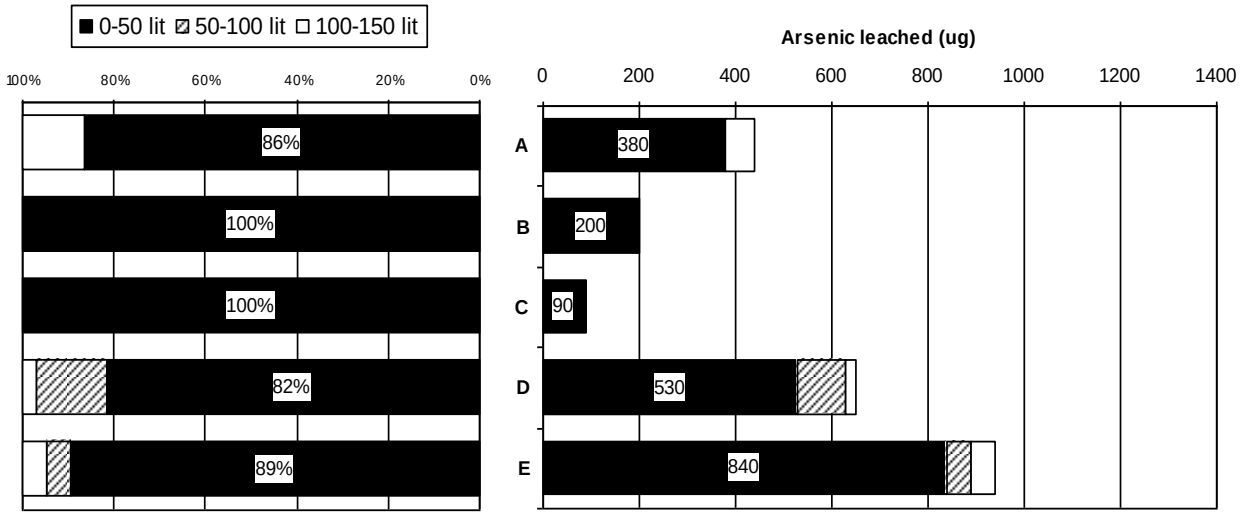
Factory 3 (5 filters)



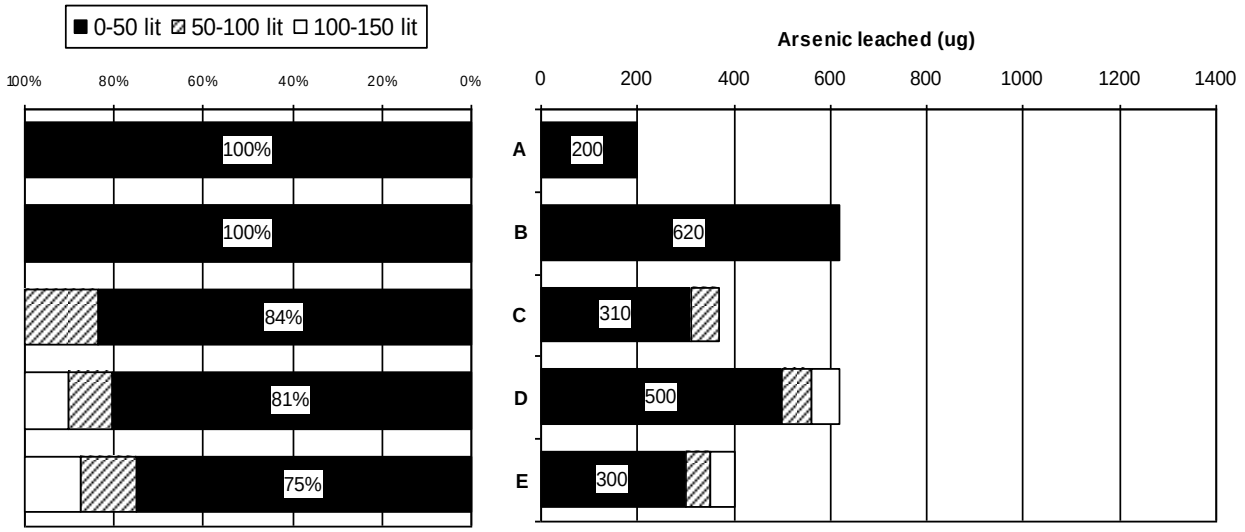
Factory 4 ***(5 filters)***



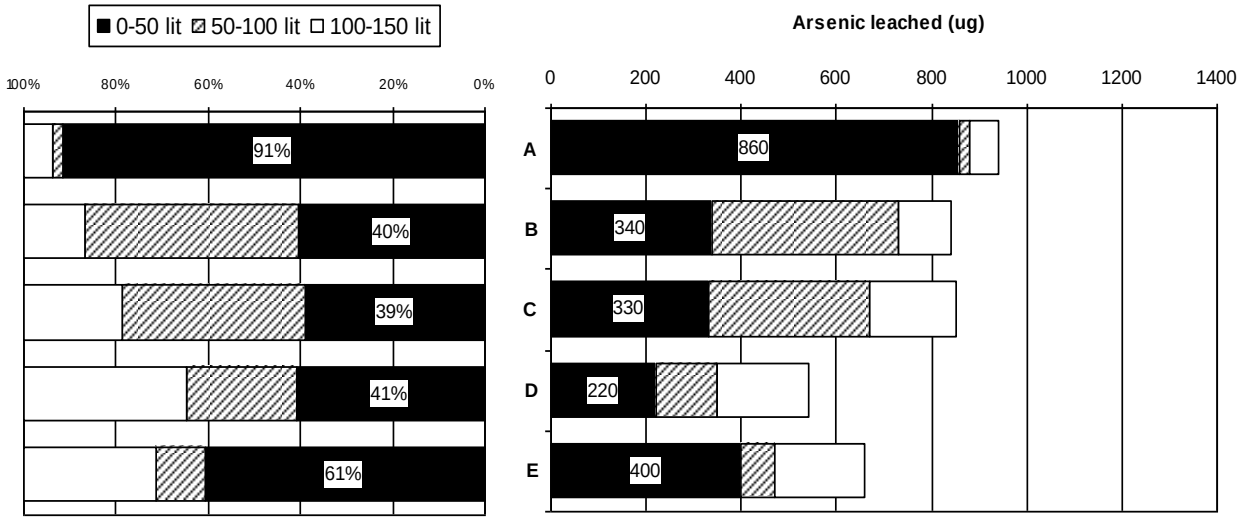
Factory 5 ***(5 filters)***



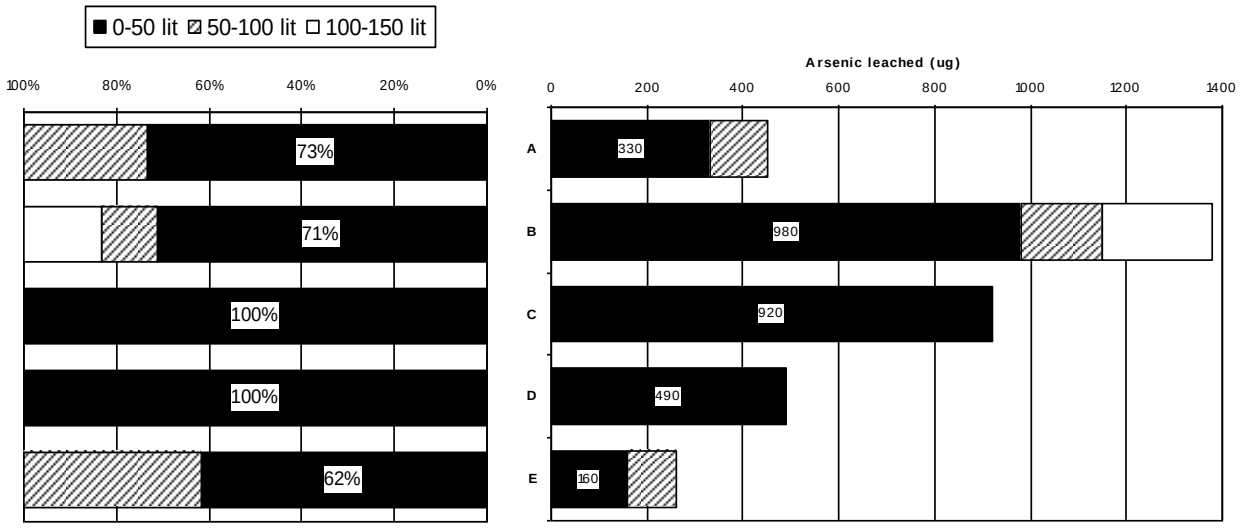
Factory 6 ***(5 filters)***



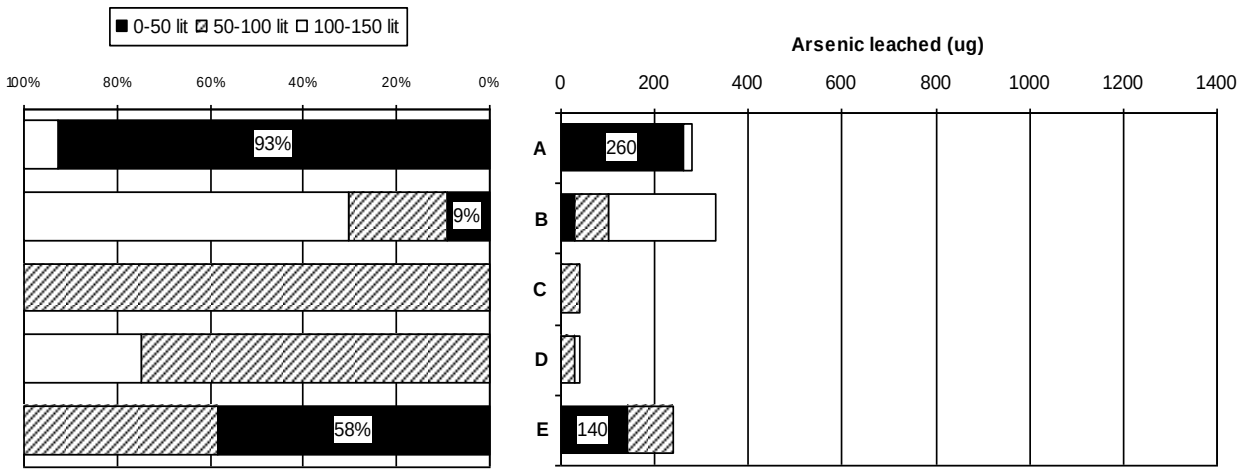
Factory 7 ***(5 filters)***



Factory 8 ***(5 filters)***



Factory 9 ***(5 filters)***

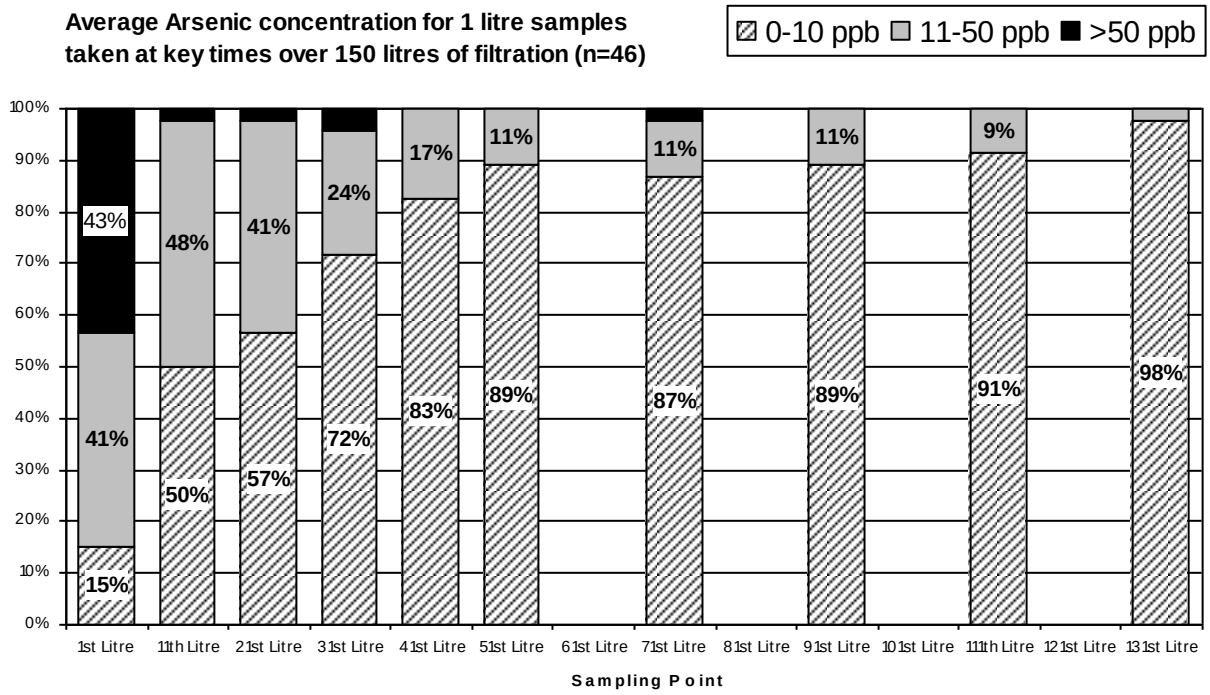


Annex 06: Arsenic concentration of 1-litre samples taken at key points over the first 150 litres of use

Arsenic Concentration	Point of Sampling									
	1st Litre	11th Litre	21st Litre	31st Litre	41st Litre	51st Litre	71st Litre	91st Litre	111th Litre	131st Litre
0-10 ppb	7	23	26	33	38	41	40	41	42	45
11-50 ppb	19	22	19	11	8	5	5	5	4	1
>50 ppb	20	1	1	2	0	0	1	0	0	0
TOTAL	**46**	**46**	**46**	**46**	**46**	**46**	**46**	**46**	**46**	**46**

Arsenic Concentration	Point of Sampling									
	1st Litre	11th Litre	21st Litre	31st Litre	41st Litre	51st Litre	71st Litre	91st Litre	111th Litre	131st Litre
0-10 ppb	15%	50%	57%	72%	83%	89%	87%	89%	91%	98%
11-50 ppb	41%	48%	41%	24%	17%	11%	11%	11%	9%	2%
>50 ppb	43%	2%	2%	4%	0%	0%	2%	0%	0%	0%

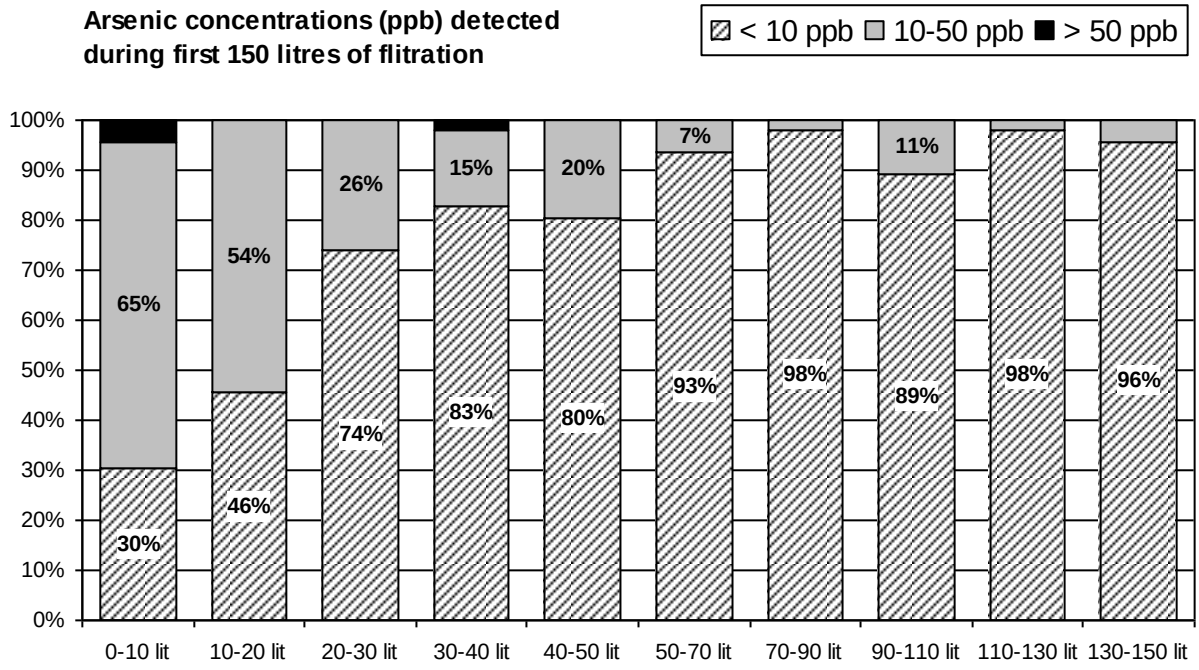
Average Arsenic concentration for 1 litre samples taken at key times over 150 litres of filtration (n=46)



Annex 07: Average Arsenic concentration of samples taken consecutively over the first 150 litres of use

Average Arsenic Concentration	Number of Filters									
	0-10 litres	10-20 litres	20-30 litres	30-40 litres	40-50 litres	50-70 litres	70-90 litres	90-110 litres	110-130 litres	130-150 litres
0-10 ppb	14	21	34	38	37	43	45	41	45	44
11-50 ppb	30	25	12	7	9	3	1	5	1	2
>50 ppb	2	0	0	1	0	0	0	0	0	0
TOTAL	**46**	**46**	**46**	**46**	**46**	**46**	**46**	**46**	**46**	**46**

Average Arsenic Concentration	Percentage of filters									
	0-10 litres	10-20 litres	20-30 litres	30-40 litres	40-50 litres	50-70 litres	70-90 litres	90-110 litres	110-130 litres	130-150 litres
0-10 ppb	30%	46%	74%	83%	80%	93%	98%	89%	98%	96%
11-50 ppb	65%	54%	26%	15%	20%	7%	2%	11%	2%	4%
>50 ppb	**4%**	0%	0%	**2%**	0%	0%	0%	0%	0%	0%



Annex 08: Maximum Arsenic concentrations detected from 46 filters during the first 150 litres of filtration

A 1-litres samples taken at key points over the first 150 litres of filtration

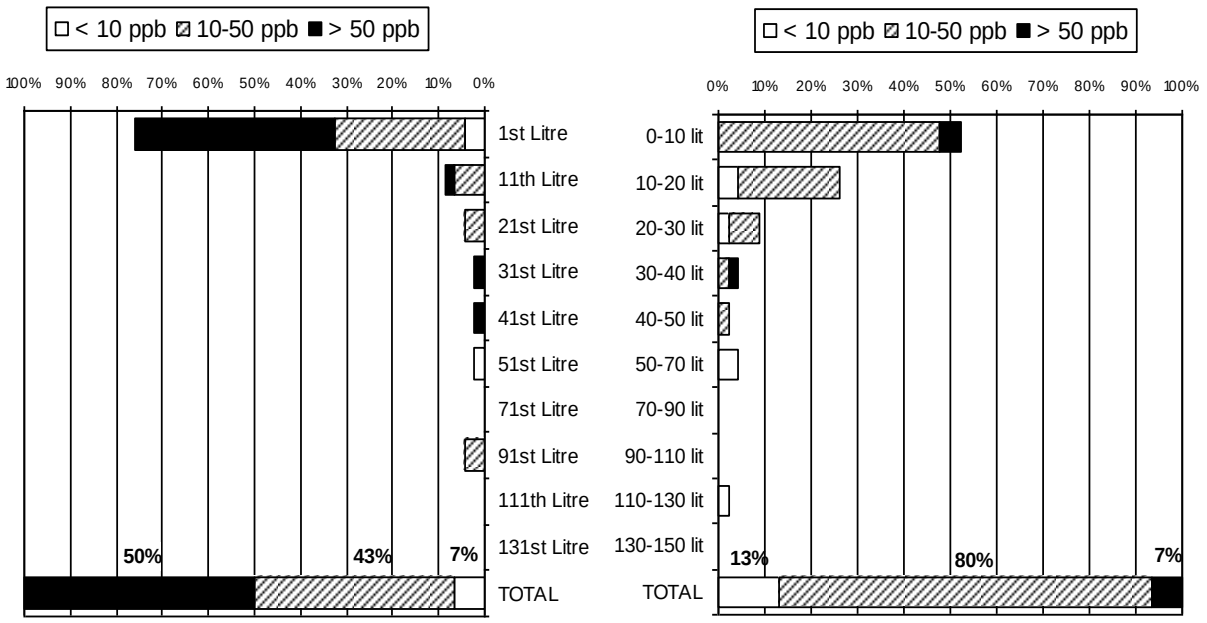
Arsenic	1st Litre	11th Litre	21st Litre	31st Litre	41st Litre	51st Litre	71st Litre	91st Litre	111th Litre	131st Litre	TOTAL
> 50 ppb	20	1	-	1	1	-	-	-	-	-	23
10-50 ppb	13	3	2	-	-	-	-	2	-	-	20
< 10 ppb	2	-	-	-	-	1	-	-	-	-	3
# Filters	**35**	**4**	**2**	**1**	**1**	**1**	**0**	**2**	**0**	**0**	**46**

Arsenic	1st Litre	11th Litre	21st Litre	31st Litre	41st Litre	51st Litre	71st Litre	91st Litre	111th Litre	131st Litre	TOTAL
> 50 ppb	43%	2%	-	2%	2%	-	-	-	-	-	50%
10-50 ppb	28%	7%	4%	-	-	-	-	4%	-	-	43%
< 10 ppb	4%	-	-	-	-	2%	-	-	-	-	7%
# Filters	**76%**	**9%**	**4%**	**2%**	**2%**	**2%**	**0%**	**4%**	**0%**	**0%**	**100%**

B Samples taken consecutively over the first 150 litres of use

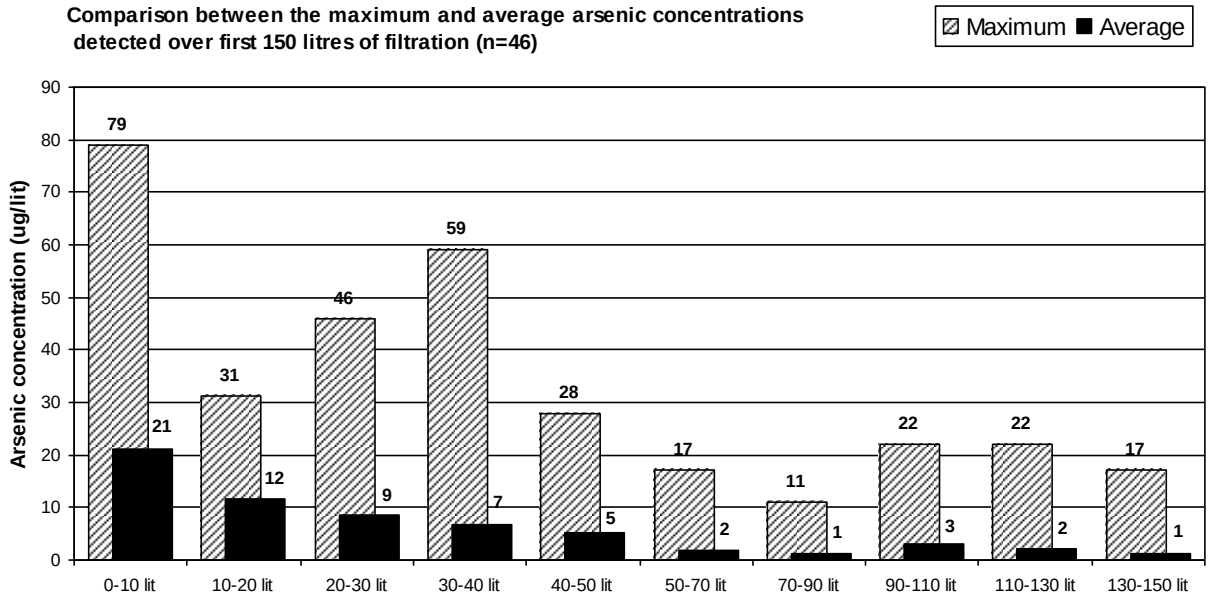
Arsenic	0-10 litres	10-20 litres	20-30 litres	30-40 litres	40-50 litres	50-70 litres	70-90 litres	90-110 litres	110-130 litres	130-150 litres	TOTAL
> 50 ppb	2	-	-	1	-	-	-	-	-	-	3
10-50 ppb	22	10	3	1	1	-	-	-	-	-	37
< 10 ppb	-	2	1	-	-	2	-	-	1	-	6
# Filters	**24**	**12**	**4**	**2**	**1**	**2**	**0**	**0**	**1**	**0**	**46**

Arsenic	0-10 litres	10-20 litres	20-30 litres	30-40 litres	40-50 litres	50-70 litres	70-90 litres	90-110 litres	110-130 litres	130-150 litres	TOTAL
> 50 ppb	4%	-	-	2%	-	-	-	-	-	-	7%
10-50 ppb	48%	22%	7%	2%	2%	-	-	-	-	-	80%
< 10 ppb	-	4%	2%	-	-	4%	-	-	2%	-	13%
# Filters	**52%**	**26%**	**9%**	**4%**	**2%**	**4%**	**0%**	**0%**	**2%**	**0%**	**100%**



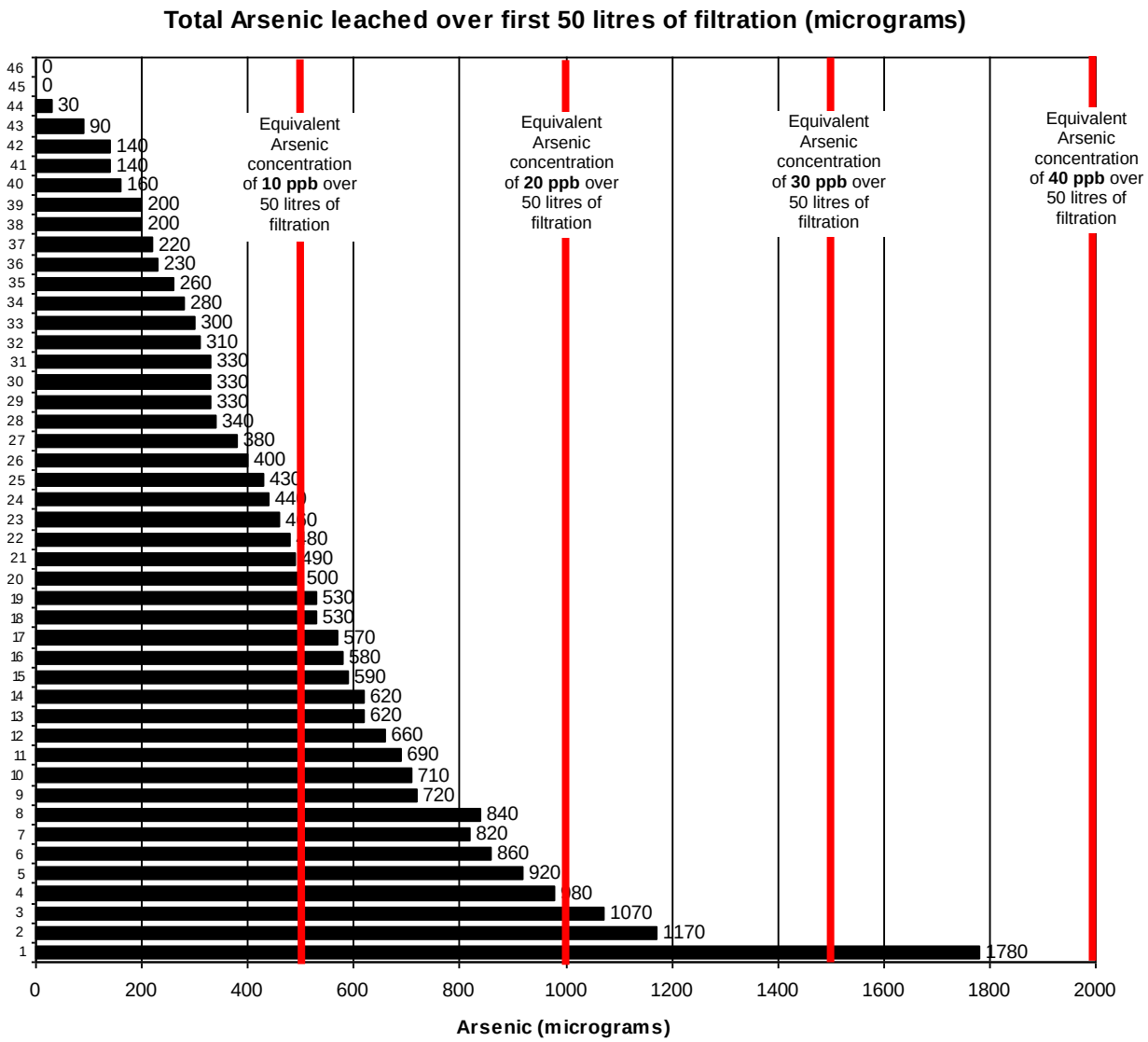
Annex 09: Comparison between the maximum and average arsenic concentrations detected for sample taken consecutively over the first 150 litres of filtration (n=46)

Arsenic concentration (ppb)	Volume of Raw Water Filtered through a new CWF									
	0-10 litres	10-20 litres	20-30 litres	30-40 litres	40-50 litres	50-70 litres	70-90 litres	90-110 litres	110-130 litres	130-150 litres
Average concentration	**21**	**12**	**9**	**7**	**5**	**2**	**1**	**3**	**2**	**1**
Maximum concentration	79	31	46	59	28	17	11	22	22	17



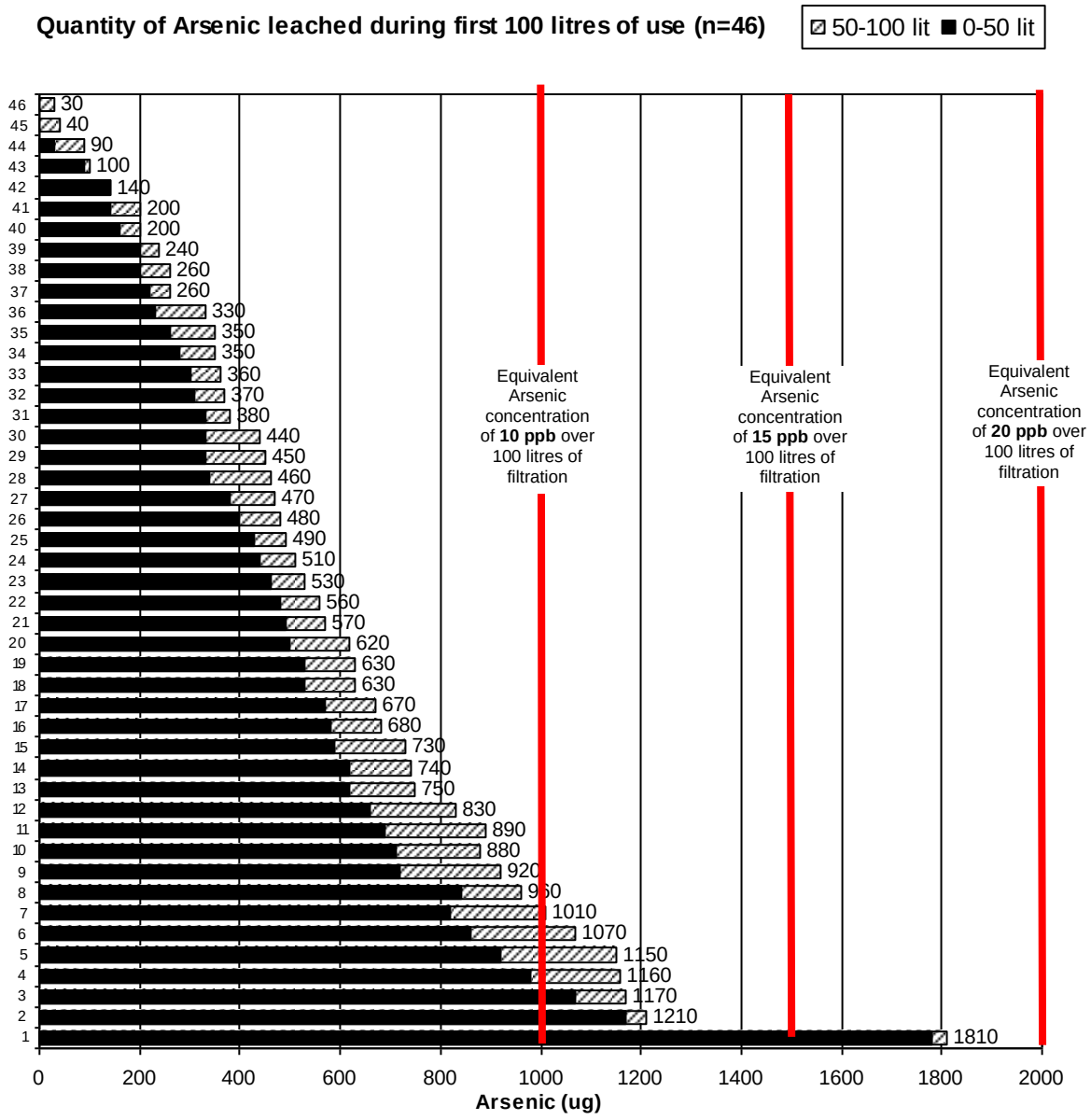
Annex 10 Total Arsenic leached over 50 litres, 100 litres and 150 litres of filtration

A Total Arsenic leached over first 50 litres of Filtration



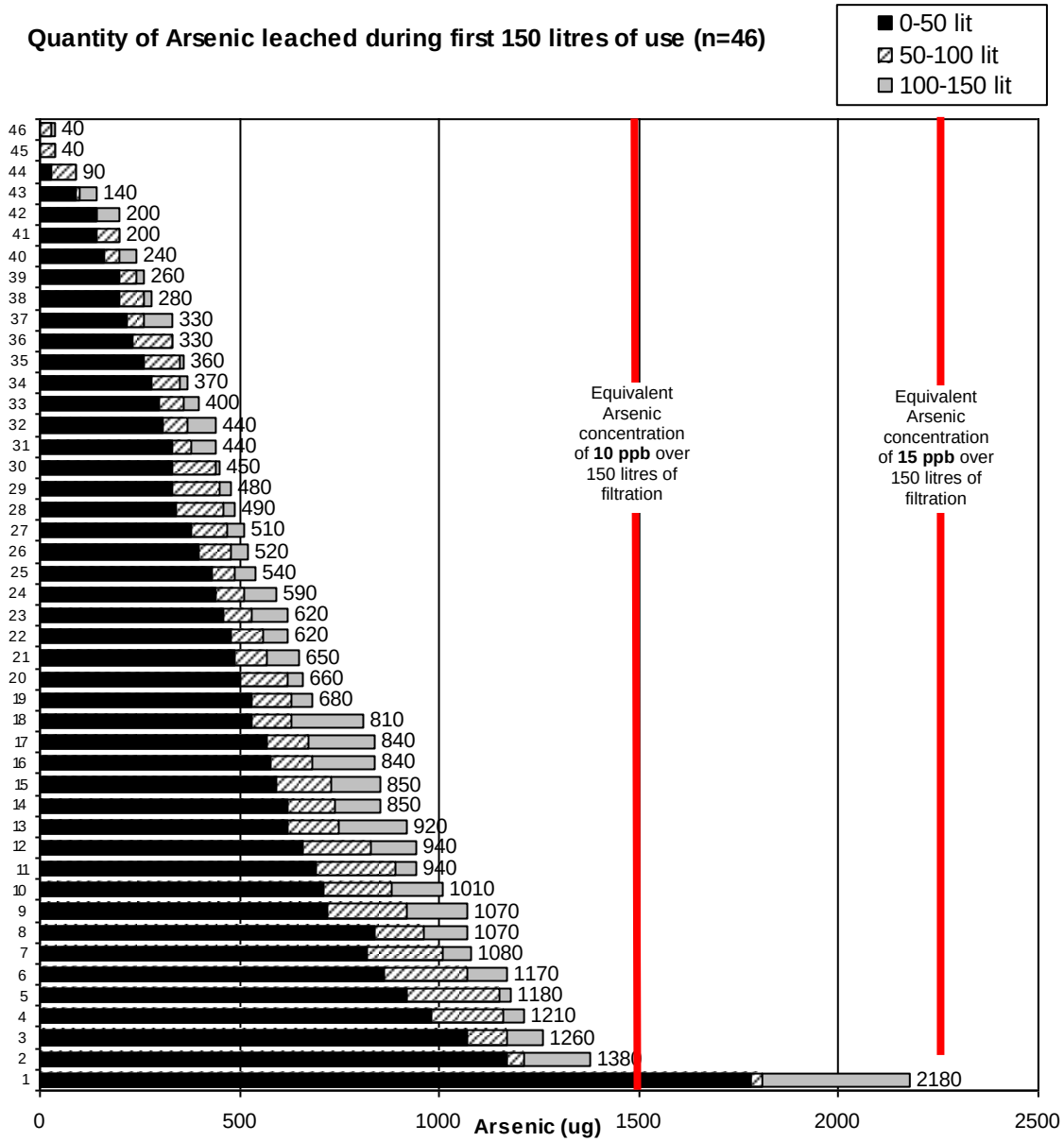
Arsenic	Number of Filters	% of Filters
< 10 ppb	27	59%
11 – 20 ppb	16	35%
21 – 30 ppb	2	4%
31 – 41 ppb	1	2%

B Total Arsenic leached over first 100 litres of filtration



Arsenic	Number of Filters	% of Filters
< 10 ppb	39	85%
11 – 20 ppb	7	15%
21 – 30 ppb	0	0%
31 – 41 ppb	0	0%

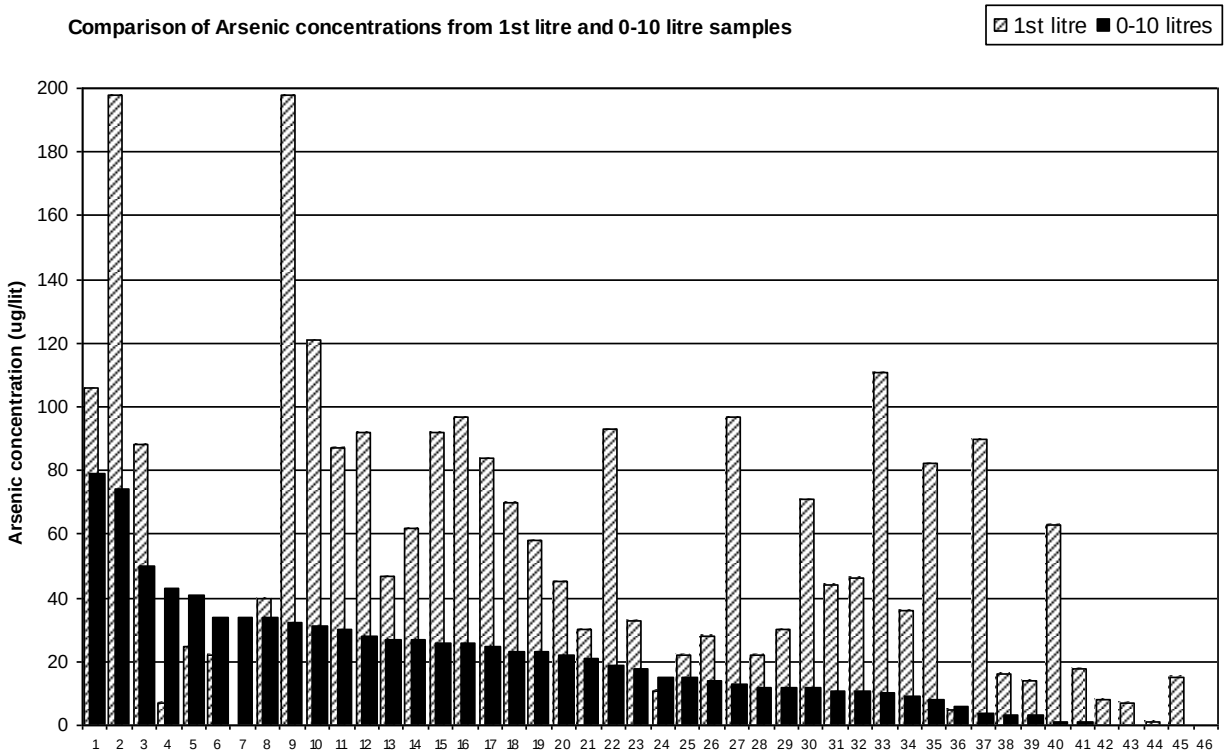
C Total Arsenic leached over first 150 litres of filtration

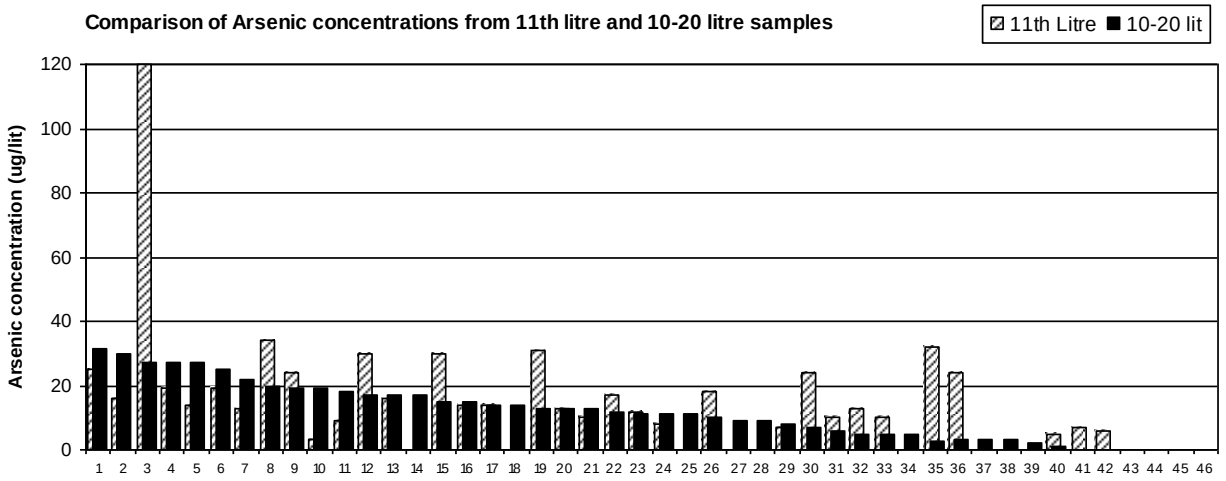


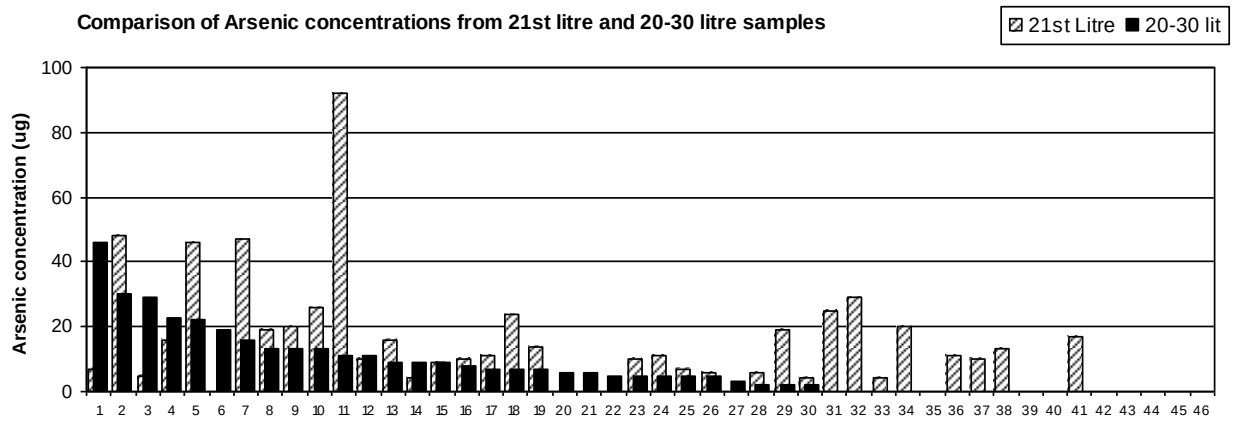
Arsenic	Number of Filters	% of Filters
< 10 ppb	45	98%
11 – 20 ppb	1	2%
21 – 30 ppb	0	0%
31 – 41 ppb	0	0%

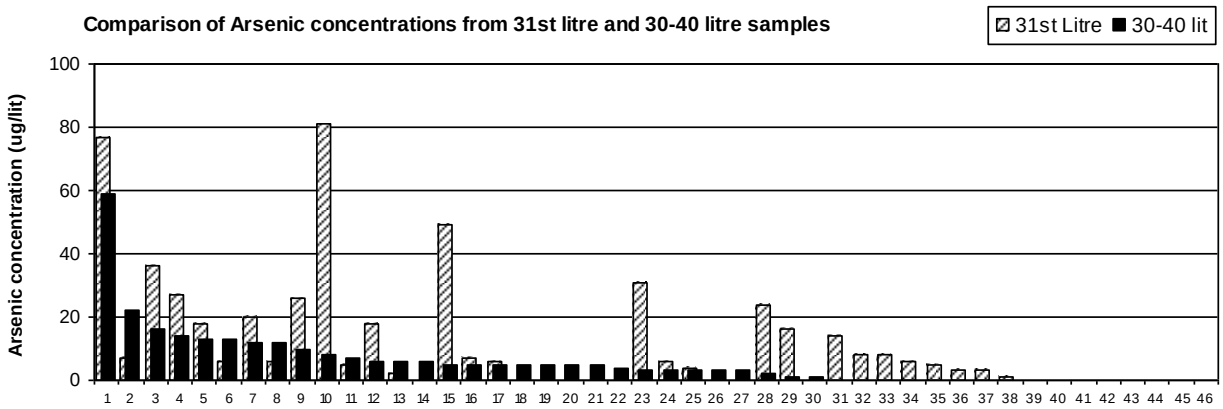
Annex 11: A comparison between the average Arsenic concentrations of 10-litre and 20-litre samples taken consecutively throughout the first 150 litres of filtration against 1-litre samples taken at key points (n=46)

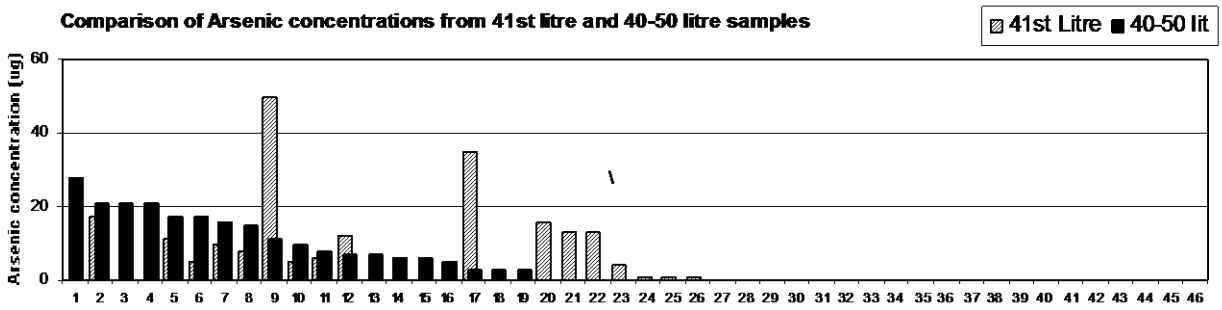
Note that the 46 filters are NOT presented in the same order in each of the figures below. Consequently, it is not possible to use these charts to follow each filter individually. The data is presented in order of the highest concentrations detected during each of the consecutive 10-litre and 20-litre samples.

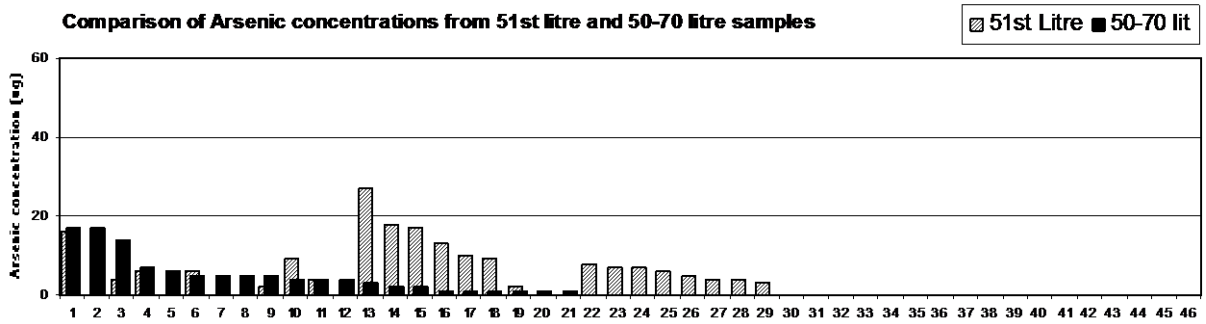


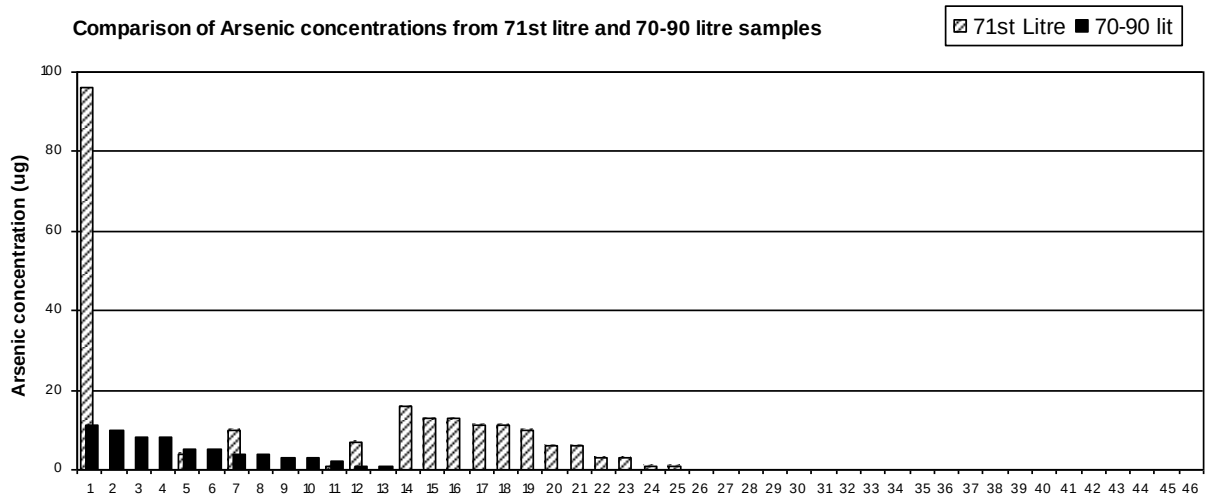


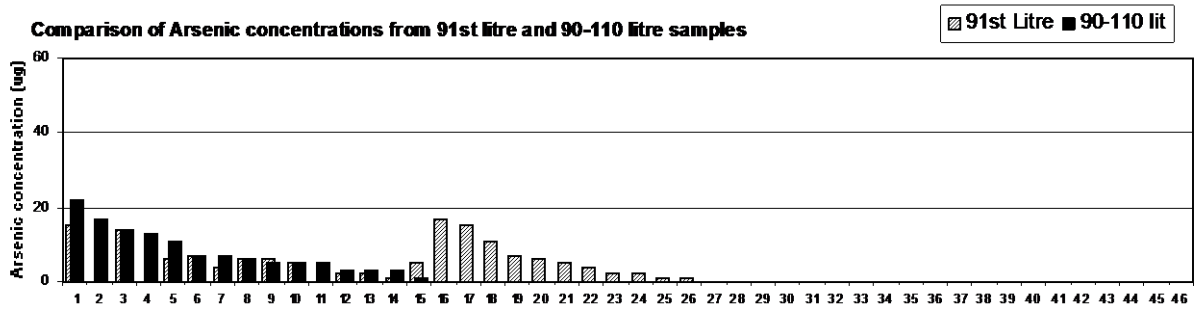

Comparison of Arsenic concentrations from 21st litre and 20-30 litre samples
21st Litre
20-30 lit
Arsenic concentration (ug)

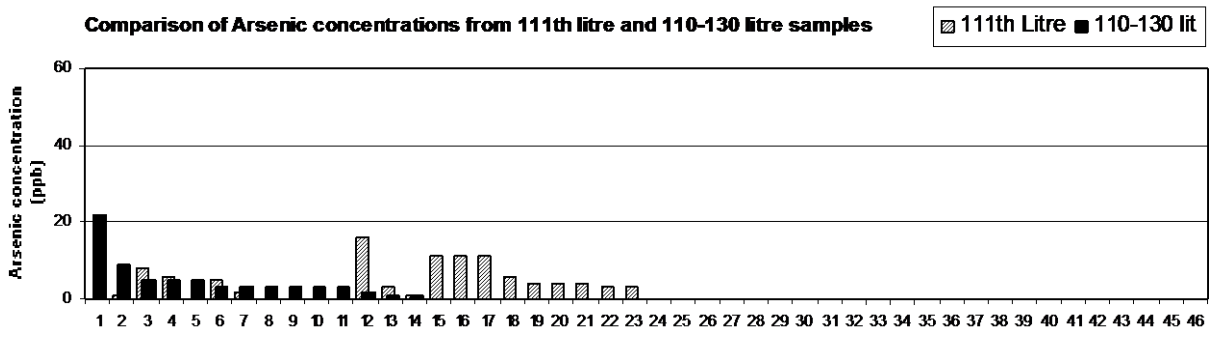

Comparison of Arsenic concentrations from 31st litre and 30-40 litre samples
31st Litre
30-40 lit
Arsenic concentration (ug/lit)

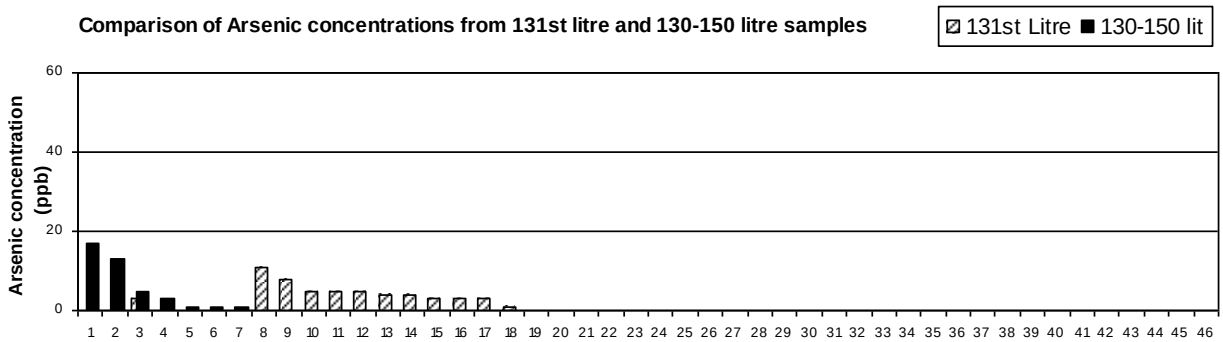

Comparison of Arsenic concentrations from 41st litre and 40-50 litre samples
41st Litre
40-50 lit
Arsenic concentration (ug)


Comparison of Arsenic concentrations from 51st litre and 50-70 litre samples
51st Litre
50-70 lit
Arsenic concentration (ug)


Comparison of Arsenic concentrations from 71st litre and 70-90 litre samples
71st Litre
70-90 lit
Arsenic concentration (ug)
0
20
40
60
80
100
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40 41 42 43 44 45 46


Comparison of Arsenic concentrations from 91st litre and 90-110 litre samples
91st Litre
90-110 lit
Arsenic concentration (ug)
0
20
40
60
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40 41 42 43 44 45 46


Comparison of Arsenic concentrations from 111th litre and 110-130 litre samples
111th Litre
110-130 lit
Arsenic concentration (ppb)
0
20
40
60
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40 41 42 43 44 45 46


Comparison of Arsenic concentrations from 131st litre and 130-150 litre samples
131st Litre
130-150 lit
Arsenic concentration (ppb)
0
20
40
60
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40 41 42 43 44 45 46