5 JANUARI 2021

PERSONAL DEEPENING

CLEAN WATER IN THE FAVELAS

LAUREN VAN RIJSWIJCK
UNIVERSITY OF TWENTE

Contents

Clean water in the *favelas*

Introduction

Safe water is very important for public heath, it can be used for many things such as, drinking, food production or recreational purposes. If the water supply in the global south improves, it will boost the country's economic growth. In addition to this, it will also contribute to poverty reduction (WHO, 2019).

Inappropriately managed water exposes individuals to health risks, the contaminated water is linked to transmission of diseases. These are diseases such as 'cholera, diarrhoea, dysentery, hepatitis A, typhoid and polio' (WHO, 2019). An estimated 829 000 people die each year from diarrhoea, due to unsafe drinking-water (WHO, 2019). Waterborne illness is caused by the contamination of water due to disease-causing microbes or pathogens (Causes and, 2019). The poor lack adequate supplies of safe water, due to this they are more susceptible to illness than the well-off. Many studies have shown that if a community improves its water supply. Afterwards, there sanitation and health improves (Water for, 2019). With basic water, dairrhoea for example, can be reduced by 26% (Water for, 2019).

The picture down below shows the inequality when it comes to the water supply in South-America.

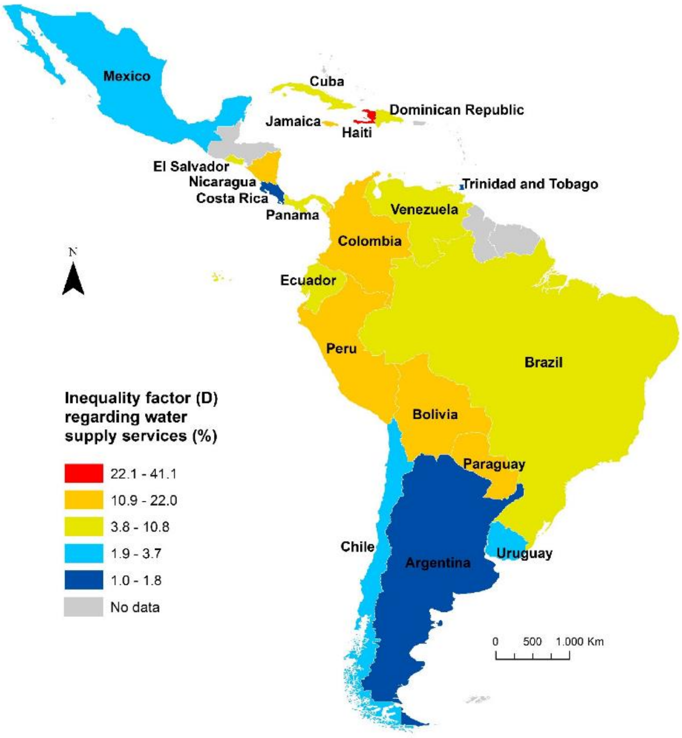

Figure 1, inequality factor regarding water supply services.

Main causes of death

The main cause of death in the developing world when it comes to illness is diarrhoeal diseases. About 2.2 million people die from diarrhoea every year. 90% of these deaths are children, most of these deaths are in developing countries (WHO, 2019). One specific single type of bacteria: Shigella, has caused a significant number of deaths. The bacteria causes dysentery or bloody diarrhoea. This can be improved by improving water supply, the simple act of washing your hands reduces this type of diarrhoea by up to 35% (WHO, 2019). The central symptom of the waterborne diseases in the world is diarrhoea, latest research has shown that diarrhoea is the second leading cause of death for young children (7 most, 2019). This means that diarrhoea causes more deaths than AIDS, malaria and measles combined.

Seven most common waterborne diseases (lifewater, 2019)

1. Typhoid fever, this is a well-known fever in very poor parts of developing nations. Up to 20 million people suffer from the illness every year. The virus can be spread through contaminated food, unsafe water and poor sanitation.
   Prevention: when travelling to such a developing countries, vaccines are recommended. Furthermore, do not drink or eat food from villages or street vendors. When infected with typhoid, it is treated with antibiotics.
2. Cholera, this disease is mainly found in villages where poverty and poor sanitation are rampant. The disease is spread through contaminated water, the disease causes severe dehydration and diarrhoea. The disease can be fatal within days or even hours. But, only 1 out of 10 people actually develops life-threatening symptoms.
   Prevention: wash your hands often, only eat foods that are completely cooked and drink safe water.
3. Giardia, this disease is shared through contaminated water. There is a parasite in the water that causes an infection which mostly clears up after a few weeks. However, some who have had the infection will still experience problems for years.
   Prevention: wash your hands often, only drink bottled water.
4. Dysentery, this disease is characterized by diarrhoea and mucus or blood in the stool. The disease is an intestinal infection, which is mainly spread through poor hygiene.
   Prevention: wash your hands often, order drinks without ice, do not eat food from street vendors, only drink sealed, bottled water.
5. Escherichia Coli (E. coli), this bacteria is found in unsafe water sources where the water sources and cattle coexist. E. coli mostly passes within a week, but younger and older people have a change of developing life-threatening symptoms.
   Prevention: cook all food thoroughly, only drink safe water, avoid water contaminated by human and animal feces.
6. Hepatitis A, this disease is a liver infection which is mainly caused by consuming contaminated water.
   Prevention: it can be avoided by getting a vaccine, only eat food that are cooked.
7. Salmonella, this disease comes from ingesting water contaminated with feces most people do not develop complications from this disease.
   Prevention: wash your hands frequently, cook your food properly.

	Spread through water?	How to prevent
Typhoid fever	Yes	Safe water, safe food,
Cholera	Yes	Safe water, safe food
Giardia	Yes	Safe water
Dysentery	Yes	Safe water, safe food
Escherichia Coli (E. coli)	Yes	Safe water, safe food
Hepatitis A	Yes	Vaccine
Salmonella	Yes	Wash hands, safe food

Table 1: diseases in Brazil

How to provide them with clean water?

Slow-filtered water has shown impressive results. Assumptions about using sand to filter water have been made, many of those being that this way is old-fashioned and ineffective because of the gravitational pull (Huisman, 2002). These assumptions have been shot down by research that illustrates, under the proper scenario, slow sand filtration is one of the most efficient ways of treating water (Slow sand, 2012). This method is a frugal, cheap, yet effective method, being more effective than faster ways of filtering water for disinfection. Furthermore, this method is superior because it uses local, accessible materials and can be easily taught in any community (Huisman, 2002).

In order to properly filter the water, the filter needs to filter the water in such a way that it satisfies the minimum quality that water has to have. To achieve this quality, parasites and pathogenic organism have to be reduced or inactivated, so that they do not constitute a hazard to the consumer (Sand filtration, 2015). Furthermore, the present toxic and radioactive substances must not exceed the maximum permissible levels. These measures are all found in the international standards for drinking water (WHO, 2020).

It is of importance that the favelas still have enough water supply in the future, this means that the water source has to be of sufficient size to satisfy further demand. Due to the growth of the population and greater personal requirements, the amount of required water increases (Godfrey, 2020). Some water sources that can be used in the favelas are:

1. Rain water
2. Rivers
3. Sewage water
4. Some favelas: sources of public water

International standards for drinking water

To make sure that the water is safe, the water should have a balanced PH level, be contaminant-free and should have naturally occurring minerals (WHO, 2020).

Balanced PH level

- Balanced PH level, the PH level of the water should be between 6.5 to 8.5 (Ask the, 2018). When the water level is lower than 6.5, it means that the water is more acidic. The water will contain more manganese, copper and iron. Sadly, these metals can be toxic in large amounts. This means that more acidic water poses a health risk (Trygar, 2013).

  When the PH level of the water is above 8.5, it is called more alkaline water. The taste of the water becomes bitter and it can lead to an increase in calcium and magnesium. The higher PH does not necessarily cause a health risk, but it causes skin to become dry and irritated (Ask the, 2018).

  1. Rain water has a high PH which lies between 5.6 to 5.8 (Scientist, 2020), this means that the rain water is slightly more acidic and not perfect for drinking. This extra acidity comes from the reaction that rain has with air pollutants and sulfur and nitrogen oxides. These pollutants are formed due to vehicles and industrial generating plants (Watson, 2013). To fix the low PH of the rain water sodium hydroxide needs to be added. Since this sodium hydroxide is present in the soap provided in the design, the rain water can be used to wash hands. In order to make the water drinkable, sodium hydroxide has to be added after filtering the water. The sodium hydroxide neutralizes the water and is not harmful to the consumers (Watson, 2013).

  2. Research has been conducted on the PH level of the water in rivers in Brazil. The average of this has been calculated and it lies between 6 and 7 PH (Caatinga, 2020). This means that the water can be used for drinking and washing hands.

  3. The PH level of the sewage water in Brazil is neutral, this means that it has a PH of 7 (Sobsey, 2019). So, the water is drinkable and it can be used to was hands.

  4. The PH of the sources of public water lies between 4.0 and 8.0 (Water, 2020). This makes it difficult to say if the water is safe to drink or not. To make sure if the water has the right PH tests should be conducted on this water. The mean of this PH is 4.8, which is too low. So, the same rules apply to this water as to the rain water.

	Rain water	Rivers	Sewage water	Sources of public water
PH	5.6-5.8	6-7	7	4.0-8.0
Drinkable	No	Yes	Yes	No
Washing hands	Yes	Yes	Yes	Yes
What to do to make drinkable	Add sodium hydroxide	-	-	Add sodium hydroxide

Table 2: Overview of PH water sources favelas.

When the water flows through the filter, the total PH of the water increases. On average the PH increases with 0.8 (Does the, 2017). This means that no sodium hydroxide has to be added to the rain water to make it drinkable. This is not the case for some of the public water in the Brazilian favelas.

Contaminant-free

- Contaminant-free, there are several types of water contaminants that affect people's health: 'microorganisms, inorganic chemicals, organic chemicals and disinfection byproducts.' (Drinking water, 2019). Firstly, microorganisms are bacteria, viruses and protozoa. The microorganisms are capable of causing gastrointestinal illness (Drinking water, 2019). The filter removes 99% of the bacteria, 80%-90% of the viruses and 99.98% protozoan removal (Cawst, 2018). Secondly, research has shown that the filter filters 97.5% of chemicals. For example, 97% of atrazine, 93% of naphthalene and 100% of phenanthrene and anthracene are removed (Fierer, 2019). These are all chemical contaminants that have to be removed from the water. Lastly, the filter also has to remove disinfection byproducts, these are products such as Fe which has an average removal of 74.75%, Mn which has an average removal of 76.55%, trace lead which has an average removal of 74.07% and chromium which has an average removal of 68.82% (Simple method, 2005). Additionally, the filter also has to remove biodegradable dissolved organic carbon (BDOC). This has to be removed due to the fact that it can be metabolized by bacteria. On average, the filter removes 61.78% of the BDOC (Simple method, 2005). Another byproduct that has to be removed is Total Phosphorus (TP), this is a nutrient that is important for plant growth. Of course, no plant growth should take place in either the filter or clean water, the filter removes 68.62% of this nutrient (Total Phosphorus, 2019).

contaminants	examples	Removal
Microorganisms	Bacteria	99%
	Viruses	80%-90%
	Protozoa	99.98%
Chemicals	Atrazine	97%
	Naphthalene	93%
	Phenanthrene	100%
	Anthracene	100%
Disinfection byproducts	Fe (iron)	74.07%
	Mn (manganese)	76.55%
	Trace lead	74.07%
	Chromium	68.82%
BDOC		61.78%
TP		68.82%

Table 3: Average removal of some contaminants by the filter

This information shows that the filter gets rid of the contaminants in the water, which means that it can be used to create proper drinking water.

Naturally occurring minerals

- Naturally occurring minerals, the minerals that most often naturally occur in water are calcium, magnesium and potassium (What are, 2020). When the water flows through the filter, the total dissolved solids also increase. This is due to the fact that the water takes up minerals from the sand (CAWST, 2020). The filter itself does not remove any calcium, magnesium or potassium from the water (BSF, 2020).

Minerals	Removed by filter?	Too much dangerous?	Highest ever measured in water (mg/l)	Suggested amount per day (mg)
Calcium	No	Yes	47	590
Magnesium	No	Yes	10.6	300
Potassium	No	Yes	0.5	3500

Table 4: Information about the effects of minerals. (Biosand Filter, 2018)

As shown in the table, the amount of minerals present in the water is much smaller than the amount that is allowed per day. This means that we can neglect that dangerous results the minerals might have. Furthermore, the minerals are not filtered by the filter and they are present in the water and added by the filter. So, the minerals are present in the eventually clean drinking water.

Minerals present in water sources

1. Rain water,

	Ppt	pH	C	H^+	Na^+	K^+	Ca^{2+}	Mg^{2+}	SO_4^{2-}	NO_3^-	Cl^-	SiO_2	Al	Zn	Fe	Sr	Cu	Mn	Ba	Ni	Pb	Rb	Mo	V
Boa Vista																								
VWM		4.5	4.6	63.0	55.9	4.5	52.4	4.4	1.6	4.7	10.2	1.2	1952	655	426	141	77	93	15	23	4	4	2	3
VWMW		4.5	4.7	64.3	61.5	4.8	58.8	4.9	1.6	4.5	10.2	1.2	2147	616	461	157	84	103	15	24	4	4	1	4
VWMD		4.4	3.6	53.6	14.4	2.0	6.2	0.6	1.9	6.3	10.5	0.7	522	938	173	18	26	18	14	15	1	2	7	1
Mean	166.0	4.7	4.4	38.9	37.0	3.9	24.5	2.2	2.3	10.7	16.5	1.6	1016	487	237	70	70	48	15	27	2	4	3	2
Min	0.0	4.0	2.9	1.6	6.0	0.8	1.7	0.2	<DL	1.0	1.4	0.02	124	45	50	1	16	3	2	3	1	1	<DL	<DL
Max	562.3	5.8	5.9	100.0	207.1	12.7	213.0	16.2	7.0	39.6	113.1	6.2	7077	1917	1476	579	162	363	47	135	11	12	16	12
Sd2	196.8	0.6	1.2	39.4	61.2	4.0	62.7	4.8	2.0	12.3	32.4	2.3	2017	673	417	172	59	106	17	38	3	4	5	4
Manaus open-area																								
VWM		4.1	8.3	114.7	15.4	3.2	17.1	2.1	9.5	12.3	10.1	0.7	951	309	312	44	55	40	5	37	1	4	8	24
VWMW		4.2	8.5	117.8	13.2	2.4	11.7	1.6	5.5	9.6	7.6	0.6	781	235	237	31	41	33	5	27	1	3	8	19
VWMD		4.1	7.1	93.6	30.0	8.9	53.7	5.2	36.3	30.8	27.1	1.7	2088	807	809	131	152	85	5	101	1	9	2	54
Mean	204.4	4.1	7.9	104.5	21.6	5.2	29.7	3.2	18.7	19.3	18.0	1.1	1371	486	489	93	91	56	5	58	1	6	6	35
Min	38.7	3.4	4.9	12.6	1.3	0.6	3.4	0.3	2.6	0.0	1.9	0.3	384	62	84	2	11	5	<DL	11	<DL	1	<DL	4
Max	437.2	4.9	14.3	398.1	80.8	14.3	82.2	9.2	46.4	51.4	82.9	2.7	2914	1221	1233	677	256	120	24	199	2	16	26	77
Sd2	137.4	0.4	2.8	101.5	20.3	4.4	27.8	2.6	19.4	17.3	22.0	0.7	876	436	392	187	89	36	8	60	1	5	9	29
Manaus under-canopy																								
VWM		4.1	17.4	81.9	31.7	20.0	111.4	11.4	30.7	17.4	19.3	2.8	1457	318	402	201	50	211	29	29	5	26	4	26
VWMW		4.2	17.3	73.1	24.4	17.2	41.7	9.1	25.6	13.0	15.6	2.4	1074	240	354	76	37	178	21	22	4	22	5	18
VWMD		3.8	19.4	162.5	95.5	43.4	673.8	31.8	79.1	61.3	58.0	6.7	4917	969	729	1189	169	489	101	89	12	55	2	97
Mean	204.4	4.0	17.9	105.4	51.9	27.6	286.6	18.5	46.3	32.0	31.8	4.3	2659	530	559	521	89	305	54	50	7	36	3	51
Min	38.7	3.7	11.4	31.6	9.3	10.2	16.4	4.4	13.0	3.9	2.8	0.9	622	111	200	25	17	57	11	11	2	12	<DL	9
Max	437.2	4.5	21.8	199.5	117.5	53.1	1218.4	40.9	84.9	76.8	79.5	9.2	6515	1348	1335	2131	208	697	137	117	16	63	16	134
Sd2	137.4	0.3	3.0	54.8	40.1	15.3	418.8	14.5	31.0	30.2	27.0	3.4	2277	415	367	787	75	235	50	39	4	20	5	51
Apuí																								
VWM		5.5	12.8	31.8	80.5	3.4	11.5	1.2	16.8	4.1	11.4	0.6	558	406	205	31	62	64	4	61	6	3	2	2
VWMW		4.8	9.1	19.6	52.2	2.7	11.2	0.8	9.0	1.6	9.6	0.6	674	421	205	33	59	48	4	63	5	2	2	2
VWMD		4.4	17.2	52.3	129.2	3.8	5.6	1.8	31.8	9.5	10.6	0.2	601	451	164	7	40	81	4	22	5	4	<DL	1

figure 2: rainwater composition Brazil (Horbe, 2010)

2. <u>Rivers,</u>

Sample	pH	Cond	Ca^{2+}	Na^{+}	K^{+}	Mg^{2+}	Cl^{-}	SiO_2	Fe	B	Sr	Pb	Se
Badajós basin-black water													
1	5.69	25.5	1.66	0.42	0.40	0.44	5.18	3.84	< 0.01	< 0.01	5.00	0.16	0.21
2	5.91	41.7	2.63	0.31	0.64	0.55	4.85	3.00	< 0.01	< 0.01	4.50	0.03	0.13
3	5.38	22.5	2.17	0.30	0.49	0.48	1.93	1.29	< 0.01	< 0.01	4.75	0.07	0.11
4	5.40	12.1	3.17	0.26	0.48	0.37	5.81	1.27	0.01	< 0.01	2.50	0.22	0.05
5	5.26	22.9	2.59	0.33	0.52	0.54	5.81	1.55	< 0.01	< 0.01	5.50	0.08	0.16
Average		24.94	2,44	0.32	0.51	0.48	4.72	2.19	0.01	< 0.01	4.45	0.11	0.13
Coari basin-black water													
6	5.53	10.7	1.24	0.39	0.43	0.39	2.03	0.66	0.04	0.01	1.75	0.21	0.1
7	5.81	10.6	0.97	0.91	0.68	0.26	4.07	4.14	0.03	0.58	1.50	0.16	0.1
8	6.01	10.7	2.44	1.23	0.70	0.59	3.05	7.76	0.09	0.91	1.75	0.26	0.2
9	5.76	18.8	0.99	1.22	0.78	0.38	2.03	8.37	0.12	0.59	2.50	0.02	0.1
10	5.60	19.0	0.54	0.89	0.57	0.35	4.07	7.15	0.18	0.28	2.50	< 0.01	NA
11	6.07	34.2	0.98	0.88	0.84	0.55	4.07	11.36	0.16	0.02	2.75	0.12	< 0.1
12	5.33	22.3	0.84	0.62	0.51	0.28	4.95	9.37	0.02	0.04	2.50	0.13	0.1
13	5.42	22.7	1.70	0.67	0.43	0.54	4.95	9.95	0.13	< 0.01	2.00	< 0.01	NA
14	5.51	39.9	1.85	0.55	0.35	0.56	1.98	8.81	0.15	< 0.01	2.75	0.14	0.1
15	5.60	18.2	1.65	0.56	0.43	0.35	2.97	6.16	0.16	< 0.01	2.75	0.23	0.2
Average		20.71	1.32	0.79	0.57	0.43	3.42	7.37	0.11	0.24	2.28	0.13	0.12

Figure 3a: *river composition Brazil (Chem, 2009)*

Smaller lakes-black water													
16	5.50	50.0	3.36	0.51	0.48	0.57	5.81	4.10	< 0.01	< 0.01	8.50	0.07	NA
17	6.90	52.9	3.86	0.55	0.58	0.67	1.94	3.82	0.02	< 0.01	9.50	0.17	0.13
18	6.20	55.5	3.86	0.66	0.87	1.21	3.87	3.70	< 0.01	< 0.01	9.75	0.07	0.14
19	6.12	70.3	3.05	0.76	0.34	1.46	3.96	4.46	0.14	< 0.01	3.25	0.18	0.12
20	7.22	70.0	3.05	0.74	0.08	1.46	2.97	3.81	0.03	< 0.01	2.25	0.15	0.14
21	6.04	71.3	3.05	0.86	0.27	1.67	2.97	3.47	< 0.01	< 0.01	13.25	0.15	0.13
Average		61.6	3.37	0.68	0.44	1.17	3.59	3.89	0.03	< 0.01	7.75	0.13	0.13
Solimões river-white water													
22	7.34	99.4	3.05	1.68	0.23	1.15	7.93	3.76	0.18	< 0.01	12.50	0.08	0.10
23	6.90	71.2	3.04	1.07	0.65	1.12	8.15	4.24	0.06	0.01	11.75	0.08	0.21
24	6.01	69.0	3.86	0.97	0.67	0.75	1.94	3.93	0.08	0.01	12.00	0.11	0.21
Average		79.9	3.32	1.24	0.52	1.01	6,01	3.98	0.11	0.01	12.08	0.09	0.17
Black-water*			< 4.5	0.1-2.9	0.1-2.1	< 0.70	0.4-3.5	4.2-6.9					
White-water*			5.3-16.4	1.8-6.0	0.9-2.0	1.0-2.3	1.7-4.9	1.5-2.1					
World river[21]			14.7	7.2	1.4	3.7	8.3	6.5					

Figure 3b: *river composition Brazil (Chem, 2009)*

3. Sources of public water,

Parameters	Wastewater		Drinking water (well)	
	Mean	Standard deviation	Mean	Standard deviation
T (°C)	21.5	4.31	19.5	3.21
pH	7.39	0.32	7.73	1.13
EC (μs/cm)	1355	37.53	519	25.12
Ca^{2+} (meq/l)	3.55	0.54	2.92	0.32
Mg^{2+} (meq/l)	1.21	0.53	1.12	0.22
Na^{+} (meq/l)	4.15	0.36	0.97	0.13
K^{+} (meq/l)	0.89	0.26	0.04	0.14
HCO_3^- (meq/l)	3.51	0.29	2.98	0.21
Cl^- (meq/l)	2.63	0.31	1.22	0.33
NO_3^- (meq/l)	1.22	0.36	0.64	0.12
SO_4^{2-} (meq/l)	1.62	0.24	0.86	0.14
PO_4^{3-} (meq/l)	1.02	0.39	0.002	0.22
SAR (meq/l)	2.64	0.28	1.56	0.17
Total solid suspend (TSS; mg/l)	158	5.51	–	–
Biological oxygen demand (BOD_5; mg/l)	175	54.39	–	–
Chemical oxygen demand (COD; mg/l)	401	88.41	–	–

Figure 4: composition public water Brazil (Khashman, 2019)

	Mean in rain water	Mean rivers	Sewage water	Sources of public water
Calcium (Ca)	24.5	3.32	-	3.55
Magnesium (Mg)	2.2	1.01	-	1.21
Potassium (K)	3.9	0.52	-	0.89

Table 5: amount of minerals present in water sources

In none of the water sources in Brazil are too many minerals present, rain water, river water and the water from public sources are all drinkable. The mineral composition of the sewage water is not clearly portrayed, but the sewage water will never have too many minerals. It is more often that case that it has almost no minerals. This means that is does not fit the international standards for drinking water, but since the water will not cause any serious harm, it is still drinkable.

Turbidity

For the drinking water to be safe, the turbidity has to be taken into consideration. The turbidity of water has to do with the clarity of the liquid. It is a measurement of the amount of light that can pass through the water, it is measures in Nephelometric Turbidity Units (NTU) (Turbidity of, 2018). When the turbidity in the water exceeds 5 NTU it is not as safe to drink (Biosand Filter, 2019), this is due to the fact that the water can shield harmful organisms so that the water cannot be disinfected properly. On average, the filter has a turbidity reduction of 93% (Biosand Filter, 2019).

1. Rain water, the average turbidity of rain water has a highest level of 22.26 NTU, after a treatment with the filter this becomes 2.26 NTU (Environ, 2019). This means that the water is safe to drink.
2. Rivers, the highest amount of turbidity found in the rivers in Brazil is 38 NTU (Medeiros, 2017). So, the filtered water will contain 2.7 NTU, which is safe to drink.
3. Sewage water, for the sewage water the turbidity differs a lot. Some of the sewage water is drinkable after filtering it but some is not.

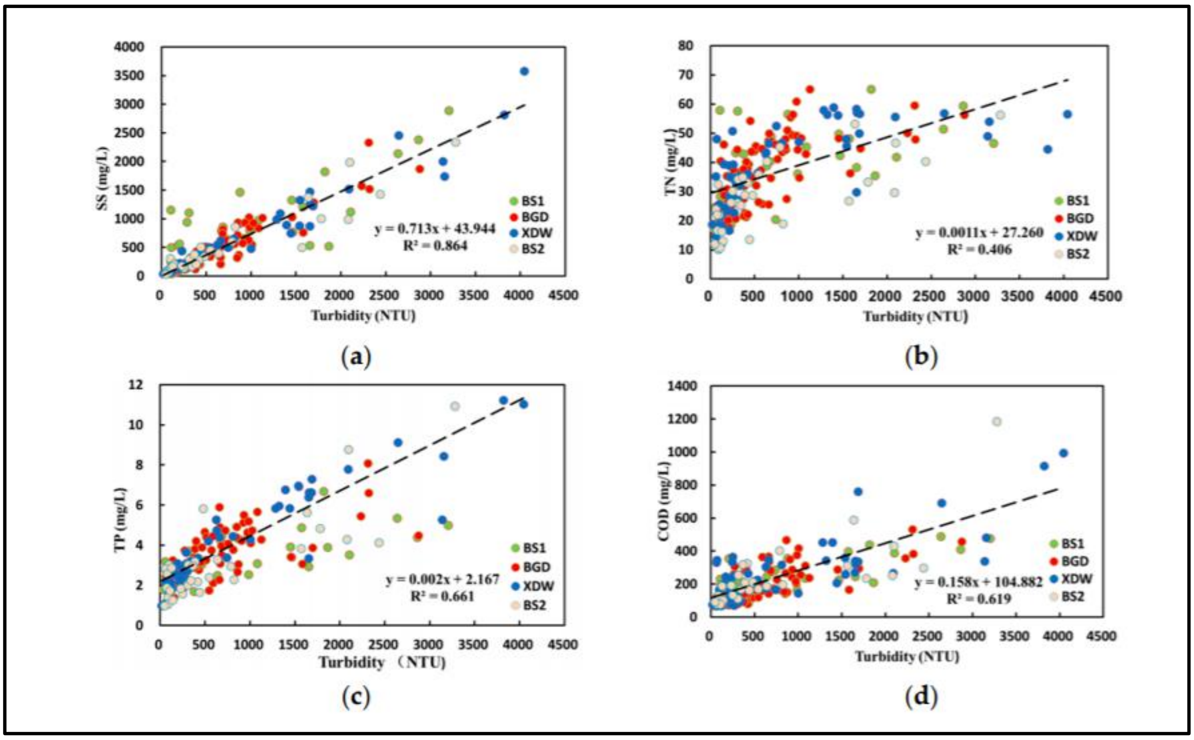

Figure 5: differences in turbidity Brazilian rivers (Romero at al., 2020)

As you can see in the figure it is difficult to determine whether the sewage water is drinkable or not. Research says that the turbidity can not be higher than 78 NTU if it needs to be cleaned by the filter (Liu et al., 2020).

4. Sources of public water, the turbidity of the public water sources has an average of 10.4 NTU (Liu et al., 2020), this means that the water can be cleaned by the filter.

	Turbidity before filtering	**Turbidity after filtering**	**Drinkable?**
Rain water	22.26 NTU	2.26 NTU	Yes
Rivers	38 NTU	2.66 NTU	Yes
Sewage water	Max. 78 NTU	Max. 5.46 NTU	Depends on the source
Sources of public water	10.4 NTU	0.73 NTU	Yes

Table 6: if the water is drinkable based on the turbidity

Layers in the filter

Each layer of the filter suits a specific purpose. Firstly, the gravel, or small stones, on the top layer, filters large contaminants, like leaves or insects. The rocks have to have a diameter between 2 cm or 4 cm and the layer should be around 5 cm thick (Water treatment, 2000).

Secondly, there are two types of sand there to remove impurities. The layer of fine sand should be around 10 cm long. The diameter of the fine sand has to be around 0.4 to 0.6 mm (Dittoe, 2002). The fine sand is used for the removal of suspended matter. Additionally, it gets rid of floating and sinkable particles. The particles are removed by absorption or physical encapsulation (Sand filtration, 2010).

figure 6: the filter

The coarse sand has a diameter of 0.6 mm to 1.0 mm. The layer of coarse sand should be around 5 cm long (Biosand, 2018). This type of sand strains out particles from the water. These particles can be contaminants or colonies of living organisms.

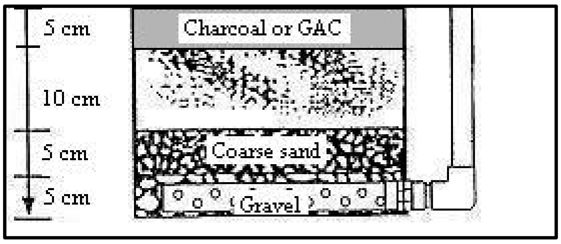

figure 7: measurements of each layer

Thirdly, the most important layer, the activated charcoal. This is extremely important, since it removes contaminants through chemical adsorption (Bryant et al., 2015). It provides an adherent surface that sticks and deactivates the contaminants. The major problem encountered when implementing this filter as a large-scale solution is obtaining the activated charcoal. Considering it is the ingredient that ultimately purifies the water from bacteria's, access to activated charcoal has to be ensured.

On a rudimentary level, charcoal can be made through a relatively easy process. Utilizing burnt wood or organic material, the charcoal can be activated by adding pulp-free lemon juice. The burnt material can be mixed with the lemon juice to a paste-like substance, and covered for 24 hours. After that, the charcoal present in the material is activated (Bryant et al., 2015).

Lastly, there is a piece of cloth, to ensure that nothing gets through the outputted water. The cloth needs to be of towel-like material, such as cotton or wool (Dittoe, 2002).

	Diameter (mm)	**Thickness layer (cm)**	**Function**
Rocks	2-4	5	Filters large contaminants
Coarse sand	0.6-1.0	5	Strain large particles
Activated charcoal	-	5	Removing contaminants through chemical adsorption
Fine sand	0.4-0.6	10	Strain small particles
Cloth	-	-	Nothing gets through the outputted water

Table 7: diameter, thickness and function of layers filter

Conclusion

To conclude, all of the water sources that we found in the *favelas* can be used for drinking. The safest sources are rain water, rivers and sources of public water. The only problem with the public water is the low PH, to test if the water is drinkable, PH test strips are needed. This is difficult to provide for every person in the *favelas.* Due to this it is suggested that they only drink the rain water and river water. Additionally, the sewage water is drinkable if the turbidity is not too high, sadly, this is hard too determine without proper testing. When it comes to all the other aspect of the sewage water, it is drinkable.

It is suggested to only drink the rain water and river water, but when proper testing on the sewage and public water is done, it can be used for drinking as well.

The filter properly cleans the suggested drinking water, thanks to this, it can be said that this design can be integrated in the *favelas* when it comes to preventing the diseases.

References:

Introduction + main cause of death + main diseases

- Adams, E. A. (2020, January 1). *Water insecurity and urban poverty in the Global South: Implications for health and human biology*. Wiley Online Library. https://onlinelibrary.wiley.com/doi/full/10.1002/ajhb.23368
- Oosterveen, H. I. (2020). *WHO World Water Day Report*. WHO. https://www.who.int/water_sanitation_health/takingcharge.html
- W.H.O. (2019, June 15). *Drinking-water*. WHO. https://www.who.int/news-room/fact-sheets/detail/drinking-water
- *Waterborne Disease - an overview | ScienceDirect Topics*. (2011). Sciencedirect. https://www.sciencedirect.com/topics/earth-and-planetary-sciences/waterborne-disease*Causes and Symptoms of Waterborne Illness - Minnesota Dept. of Health*. (2020). Health.State. https://www.health.state.mn.us/diseases/waterborne/basics.html#:%7E:text=Waterborne%20illness%20is%20caused%20by,person%2Dto%2Dperson%20spread.
- Queiroz, V. C. (2020). *New Approaches to Monitor Inequalities in Access to Water and Sanitation: The SDGs in Latin America and the Caribbean*. MDPI. https://www.mdpi.com/2073-4441/12/4/931/htm
- Kahn, C. (2020, September 29). *7 Most Common Waterborne Diseases (and How to Prevent Them)*. Lifewater International. https://lifewater.org/blog/7-most-common-waterborne-diseases-and-how-to-prevent-them/

How to provide them with clean water?

- Cairncross, S. (2003). Editorial: Water supply and sanitation: some misconceptions. *Tropical Medicine and International Health*, *8*(3), 193–195. https://doi.org/10.1046/j.1365-3156.2003.01027.x
- *Slow Sand Filtration | The Safe Water System | CDC*. (2020). Cdc.Gov. https://www.cdc.gov/safewater/sand-filtration.html
- *A23 - Sand filtration for raw water or wastewater treatment*. (2020). Wikiwater. https://wikiwater.fr/a23-sand-filtration-for-raw-water
- *waterinbrazil*. (2020). Weebly. https://waterinbrazil.weebly.com/favelas.html
- *Sand Filter - an overview | ScienceDirect Topics*. (2020). Sciencedirect. https://www.sciencedirect.com/topics/engineering/sand-filter
- Žibėnienė, G. ė. (2012). http://skktg.vdu.lt/downloads/AMK_Nr.10_78-98.pdf. *The Quality of Higher Education*, *10*, 99–122. https://doi.org/10.7220/2345-0258.10.5
- *good drinking water*. (2020). Cleanleap. https://cleanleap.com/elements-good-drinking-water

International standards for drinking water

- *Ask the Doctors – Is water with a high pH safe to drink?* (2018, August 31). Https://Connect.Uclahealth.Org/. https://connect.uclahealth.org/2018/08/31/ask-the-doctors-is-water-with-a-high-ph-safe-to-drink/
- Treatment Plant Operator. (2018, January 22). *What Exactly Is pH?* https://www.tpomag.com/editorial/2013/12/what_exactly_is_ph#:%7E:text=Raw%20wastewater%20generally%20has%20a,vary%20between%206%20and%208.
- *pH of rain and creek waters*. (2020). Soest. https://www.soest.hawaii.edu/GG/ASK/rain-creek-pH.html
- *What is acid rain? [USGS]*. (2020). Pubs. https://pubs.usgs.gov/gip/acidrain/2.html
- Honório, B. A. D., Horbe, A. M. C., & Seyler, P. (2010). Chemical composition of rainwater in western Amazonia — Brazil. *Atmospheric Research*, *98*(2–4), 416–425. https://doi.org/10.1016/j.atmosres.2010.08.001
- Ferreira, M. D. D. E. (2020). *WASTEWATER USE IN AGRICULTURE: ANALYTICAL LIMITS OF SEWAGE FOR IMPACT CONTROL IN BRAZIL*. Scielo. https://www.scielo.br/scielo.php?script=sci_arttext&pid=S1983-21252019000401048
- C. (2020b). *{{metaTags.ogTitle}}*. {{metaTags.Title}}. https://www.biosandfilters.info/faq/d026791a/does-the-biosand-filter-add-minerals-to-the-water-specifically-if-the-water-has-been-through-a-rever
- Stauber, C. E., Elliott, M. A., Koksal, F., & Sobsey, M. (2020, December 3). *Characterisation of the biosand filter for E. coli reductions from household drinking water under controlled laboratory and field use conditions*. ResearchGate. https://www.researchgate.net/figure/pH-turbidity-and-E-coli-levels-in-raw-and-BSF-filter-waters-in-the-field_tbl1_6758523
- US EPA proposes drinking water rules. (2003). *Filtration & Separation*, *40*(7), 10. https://doi.org/10.1016/s0015-1882(03)00713-4
- Issue Information. (2019). *AEM Education and Training*, *3*(2), 113–117. https://doi.org/10.1002/aet2.10108
- C. (2020c). *{{metaTags.ogTitle}}*. {{metaTags.Title}}. https://www.biosandfilters.info/faq/ecb2b914/does-the-biosand-filter-remove-all-bacteria-and-viruses
- Chan, C. C. V., Lari, K., & Soulsbury, K. (2020). An intermittently operated biochar filter to remove chemical contaminants from drinking water. *International Journal of Environmental Science and Technology*, *17*(6), 3119–3130. https://doi.org/10.1007/s13762-019-02615-w
- -. (2020). Ieee. https://ieeexplore.ieee.org/document/g
- Gottlieb, M. (2017). Hands-off Ultrasound Technique: Utilizing Simultaneous Modeling to Enhance Ultrasound Training. *AEM Education and Training*, *2*(1), 55–56. https://doi.org/10.1002/aet2.10071
- *Total Phosphorus*. (2018, February 1). RMBEL. https://www.rmbel.info/primer/total-phosphorus/#:%7E:text=Phosphorus%20is%20a%20nutrient%20important%20for%20plant%20growth.&text=Total%20phosphorus%20(TP)%20is%20a,fragments%20suspended%20in%20lake%20water.
- Eske, J. (2019, April 9). *What are the health benefits of mineral water?* Medicalnewstoday. https://www.medicalnewstoday.com/articles/324910#:%7E:text=Minerals%20that%20are%20often%20present,potassium

- C. (2020d). *{{metaTags.ogTitle}}*. {{metaTags.Title}}. https://www.biosandfilters.info/faq/e8d1dc94/does-the-biosand-filter-remove-calcium-from-the-water#:%7E:text=Calcium%20is%20typically%20a%20dissolved,to%20come%20out%20of%20solution).
- T. (2017, May 22). *Sand as a filter media*. Biosand Filter. https://www.biosandfilter.org/biosand-filter/filter-media/sand-as-a-filter-media/

Minerals present in water sources

- Honório, B. A. D., Horbe, A. M. C., & Seyler, P. (2010b). Chemical composition of rainwater in western Amazonia — Brazil. *Atmospheric Research*, *98*(2–4), 416–425. https://doi.org/10.1016/j.atmosres.2010.08.001
- Horbe, A. M. C. (2020). *Chemical composition of black-watered rivers in the western Amazon Region (Brazil)*. Scielo. https://www.scielo.br/scielo.php?pid=S0103-50532009000600018&script=sci_arttext&tlng=en
- Al-Khashman, O. A. (2020, October 11). *Chemical Evaluation of Ma'an Sewage Effluents and its Reuse in Irrigation Purposes*. ResearchGate. https://www.researchgate.net/figure/The-arithmetic-mean-of-chemical-composition-of-wastewater-and-water-well-in-Maan-city-n_tbl2_226588804

turbidity

- *Turbidity and Water*. (2020). Usgs. https://www.usgs.gov/special-topic/water-science-school/science/turbidity-and-water?qt-science_center_objects=0#qt-science_center_objects
- All PDF of this category. (2009). *Synfacts*, *2009*(09), z1045–z1057. https://doi.org/10.1055/s-0029-1217837
- Access NCBI through the World Wide Web (WWW). (1995). *Molecular Biotechnology*, *3*(1), 75. https://doi.org/10.1007/bf02821338
- *Quality index of the surface water of Amazonian rivers in industrial areas in ParÃ¡, Brazil*. (2017, October 15). ScienceDirect. https://www.sciencedirect.com/science/article/pii/S0025326X17307373
- Romero, D. D. A. (2020). *Biosand Filter as a Point-of-Use Water Treatment Technology: Influence of Turbidity on Microorganism Removal Efficiency*. MDPI. https://www.mdpi.com/2073-4441/12/8/2302/htm

Layers in the filter

- *Sand filtration | EMIS*. (2020). Emis.Vito. https://emis.vito.be/en/bat/tools-overview/sheets/sand-filtration
- T. (2017b, May 22). *Sand as a filter media*. Biosand Filter. https://www.biosandfilter.org/biosand-filter/filter-media/sand-as-a-filter-media/
- Using Slow Sand Filtration System with Activated Charcoal Layer to Treat Salon Waste Water in a Selected Community in Cape Coast, Ghana. (2015). *Journal of Advanced Chemical Engineering*, 1. https://doi.org/10.4172/2090-4568.1000135
- EPA Seeks Advice. (2001). *Science*, *294*(5551), 2453d–22453. https://doi.org/10.1126/science.294.5551.2453d
- Using Slow Sand Filtration System with Activated Charcoal Layer to Treat Salon Waste Water in a Selected Community in Cape Coast, Ghana. (2015b). *Journal of Advanced Chemical Engineering*, 1. https://doi.org/10.4172/2090-4568.1000135

- McKay, B. K. (2020, November 27). *Hydration for the Apocalypse: How to Store Water for Long-Term Emergencies*. The Art of Manliness. https://www.artofmanliness.com/articles/hydration-for-the-apocalypse-how-to-store-water-for-long-term-emergencies/#:%7E:text=Long%2DTerm%20Water%20Storage%20Solutions&text=The%20general%20guideline%20is%20to,chlorine%2C%20as%20it%20corrodes%20steel.
- Dittoe, W. H. (1922). Proper Size of Sand for Rapid Sand Filters. *American Journal of Public Health*, *12*(1), 44–49. https://doi.org/10.2105/ajph.12.1.44
- Ansari, H. (2018, March 21). *Biosand Filters: How they work, and how they change lives*. GROSCHE. https://grosche.ca/biosand-filters-all-about-them/
- T. (2017c, May 22). *Sand as a filter media*. Biosand Filter. https://www.biosandfilter.org/biosand-filter/filter-media/sand-as-a-filter-media/