ENVIRONMENTAL IMPACT STUDY

on

FIRESTONE RUBBER INDUSTRY

in **LIBERIA**

source

INTRODUCTION

Liberia is rich in natural resources and it is Africa's largest producer of natural rubber (Hevea brasiliensis). The largest concession plantations is owned by the Firestone Natural Rubber Company (Bridgestone Corporation).

Firestone operates in Liberia since 1926 with 99-years (ending in 2025) license for 404 thousand hectares of land, and it currently occupies some 61,9 thousand hectares. The total concession area of Firestone represents 4% of Liberia's territory and nearly 10% of its arable land. The Firestone industry, based in Harbel, produces ribbed smoked sheet (RSS) to be exported to the United States to produce tires.
This is a crude natural rubber in the form of brown sheets obtained by coagulating latex with acids, rolling in it into sheets, then dried by heat and smoke with the same rubberwood burning in a heating room. In the natural rubber process many environmental problems arise including air, water, and odour pollution.

According to some previous national [1] and international [2],[3] reports, the country has not much benefited from these revenues because of environmental pollution, poor attention to employees' health, and consequently social-economic problems.
Furthermore, child labour, heavy and bad working conditions, low wages, mismanagement of industrial wastes, air pollution, and water discharged have been already documented across the years [4].
In fact, Firestone was pointed for the Public Eye Award for "irresponsible corporate behavior" at the World Social Forum in Davos, Switzerland in 2007 [5].
According to local communities, it continues to provide poor working and living conditions to its employees and their families and to pollute the surrounding environment.

This research's goal is to assess environmental status quality in Harbel, part of the Margibi Country Department located in the South Coast of Liberia through:
1. Environmental screening study on air pollutants including odour and gases parameters; and
2. Fresh Water quality measurement on field and laboratory tests.

[1] Save My Future Foundation, The Heavy Load, 2008. https://laborrights.org/sites/default/files/publications-and-resources/The%20Heavy%20Load.pdf
[2] Mighty Earth, A Bridge Too Far? Social and Environmental Concerns in Bridgestone's Liberian Rubber Plantation and a Plan for Remediation, 2020. https://www.mightyearth.org/wp-content/uploads/Firestone-Liberia-full-report_2-10-20_web-ready.pdf
[3] Tarnue Johnson, A Critical Examination of Firestone'S Operations in Liberia: A Case Study Approach, 2010.
[4]Reference 1, 2, 3.
[5]Public Eye, Die "Public Eye Awards 2007" gehen an Bridgestone, Novartis und Coop, Davos 2007. https://www.publiceye.ch/de/mediencorner/medienmitteilungen/detail/die-public-eye-awards-2007-gehen-an-bridgestone-novartis-und-coop

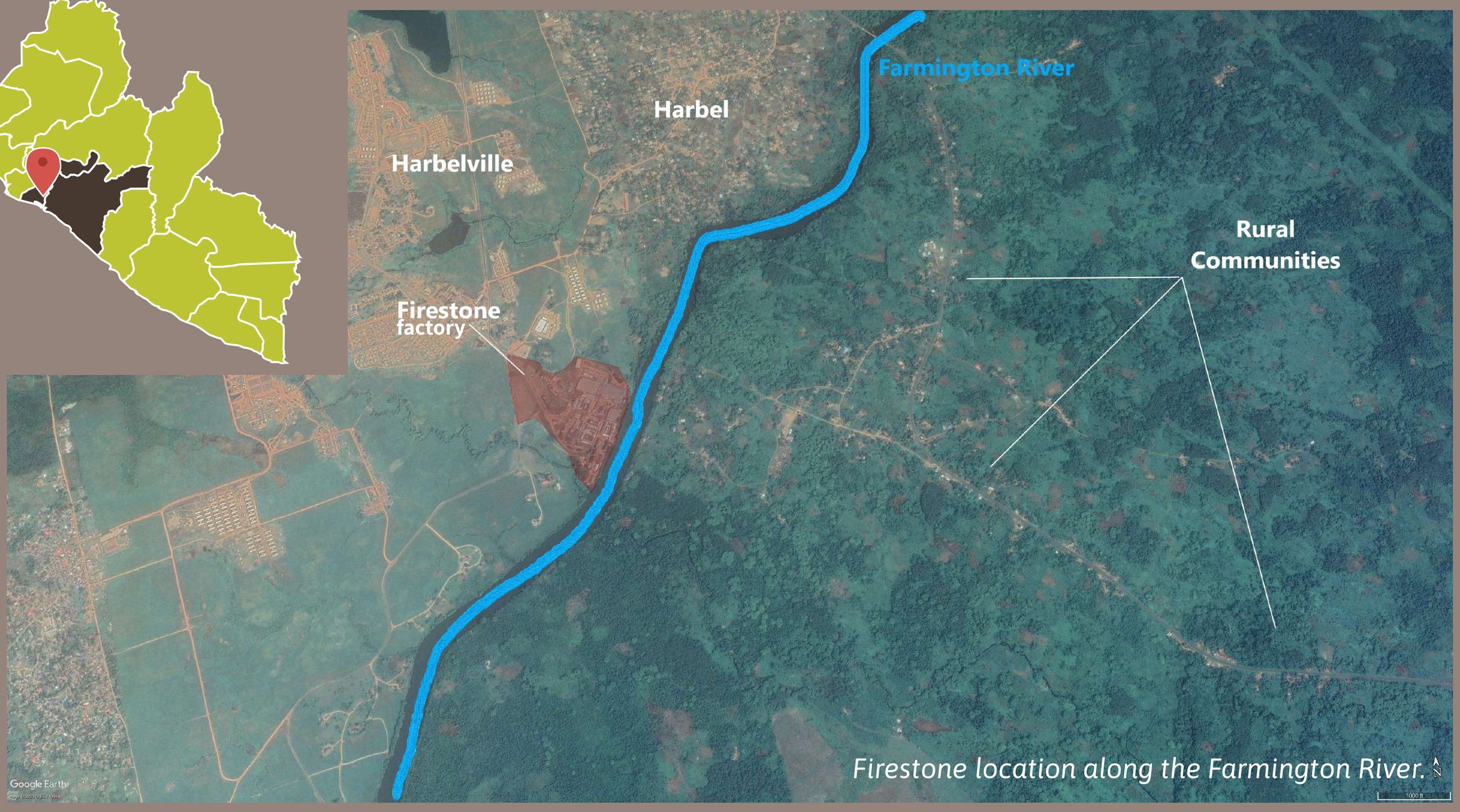
The area of study

The area of study covers roughly 170 km^2 along the banks of the Farmington River in western Liberia. It is divided into two provinces: Margibi and Grand Bassa and it includes Harbel (near the Roberts International Airport) and Harbelville (Firestone factory workers' settlements) and more than 12 different communities.

The Farmington River flows near the Firestone rubber processing plant and it represents an important water resource for thousands of people in the area for domestic use, (cooking, washing), drinkable source, subsistence agriculture, and artisanal fishing.

Access to water is not fully guaranteed. The rural population uses surface water from the Farmington River and from its tributary creeks without any previous treatment. In addition, many creeks and wells are waterless during the dry season. They also have access to water through hand-pump wells because no piped water is ensured. In some aquifers, they use chlorine to disinfect.

Hand-pump wells in rural communities.



Firestone location along the Farmington River.

Water quality assessment

The background

In 2007, Firestone built a wastewater treatment plant that includes two steps to treat 400 thousand gallons (1,48 million liters) of wastewaters weekly. Firstly, a system of tanks for equalization and clarification (in Harbel, inside the Firestone area) and secondly the discharge of that sewage into a natural wetland that acts as a polishing system, located 1,2 Km from Cotton Tree, near Kpanyah Town [6]. This wetland area acts as bio-filters removing nitrogenous compounds from the water, as the Environmental Impact Assessment (EIA) for wastewater treatment facility declared [7].
Firestone Liberia has begun a third generation of treatment programs to reduce discharges of potentially hazardous materials [8].
The water that comes from the wetland treatment system, flows into the Yur-Chu creek (Ninpu) up to the Yorma (also known as Fish) lake and finally ends up into the Fish Creek that enters later into the Farmington river again.
According to Edirisinghe J.C, the rubber industry is one of the major water polluting industries in the world. The effluents discharged consist of 60-70% of serum that contains carbohydrates, amino acids, lactic acid, which is formed in the latex. The strong chemicals added in the rubber production are also present in the same quantity in serum, such as sodium sulphites, ammonia, bisulphate, metabisulphite, and xylyl mercaptan [9].

The coagulation step involves formic acid, acetic acid [10], or sulphuric acid [11]. Solvents are used extensively in the rubber industry during the manufacturing process to prevent tackiness: aliphatic hydrocarbons, aromatic hydrocarbons (xylene, toluene, benzene), carbon disulphides, chlorinated hydrocarbons [12].

The wastewater effluents from a rubber industry can also contain oils. These oils when added into river bodies form a layer over the surface barring the oxygen to dissolve with water which results in the suffocation of animal life. It also prevents sunlight from entering and reaching to the river beds, to river plants and disrupts the process of photosynthesis, depriving fishes (that should be fished) of oxygen and resulting in death [13].

Effluents from rubber processing industries can be very harmful and they can contain total dissolved solids (TDS), total suspended solids (TSS), ammonia, phosphate, and they can be characterized by turbidity, as a measure of the degree to which the water loses its transparency due to the presence of suspended particulates, [14] and high temperature [15]. Effluents pollution is measured through chemical oxygen demand (COD) and/or biochemical oxygen demand (BOD).

Wastwater treatment system in the natural wetland area near Kpanyah Town.

[6] Firestone Liberia, Firestone's Environmental Management Plan, 2006.
[7] Firestone Liberia, Environment. https://www.firestonenaturalrubber.com/our-positions/environment/
[8] EIA Liberian Environmental Services INC, EIA for wastewaters facility, Monrovia 2008.
[9] Edirisinghe J.C et al., Community pressure and environmental compliance: case of rubber processing in Srilanka. Journal of Environmental Professionals Sri Lanka, 2013.
[10] Fair Rubber, Law price drive natural rubber into poverty. https://www.fairrubber.org/studyonworkingconditions/
[11] N.Akatova, Effect of the type of coagulant on coagulation properties of rubbers, compounds and vulcanisates, 2013.
[12] Di N. Chaiear et al., Health and Safety in the Rubber Industry. https://bit.ly/2LuNPtD
[13] Mensch U., et al., OECD Emission Scenario Document: Additives in the Rubber Industry, 2004.
[14] H.P.Jai Shanker Pillai and K.Girish, Rubber processing industry effluent treatment using a bacterial consortium, 2014. https://www.ijcmas.com/vol-3-10/H.P.Jai%20Shanker%20Pillai%20and%20K.Girish.pdf
[15] Francis Aibuedefe Igiebor, Treatment of rubber effluent from rubber processing plant with fungi, 2018. https://www.researchgate.net/publication/329806315_Treatment_of_rubber_effluent_from_rubber_processing_plant_with_fung

Methodology

Our water quality study took place between February the 25th, 2020, and March the 2nd 2020 during the dry season. The water sampling step took place on March the 2nd 2020.

SOURCE INTERNATIONAL monitored physico-chemical parameters and collected water samples in seven points around Harbel city in the Margibi department within the Farmington River basin and in the Yorma River sub-basin. In order to have background data on water quality, in non-impacted areas outside of Firestone land property, one sample of surface water from Farmington river near Poinnah Town has been additionally collected. Samples included wastewaters effluents and surface water (river).

The physical field parameters monitoring is carried out in situ, through a multiparameter probe (brand HANNA, model HI98194). The water quality parameters include:

- pH: a measure of how acidic/basic water is;
- electrical conductivity (EC): this can get an idea of how many dissolved ions are in the water;
- total dissolved solids (TDS): is a measurement of inorganic salts, organic matter, and other dissolved materials in water;
- oxidation-reduction potential (ORP): is a measure of the oxidizing or reducing potential of a water body;
- dissolved oxygen (O.D): quantity of oxygen dissolved into the water;
- salinity (PSU): saltiness or amount of salt dissolved in a body of water; and
- temperature (°C).

Surface water sampling was carried out in accordance with the international guidelines provided by the Environmental Protection Agency of the United States (US EPA) [16].
The samples were collected in different volumes of bottles as requested by the laboratory responsible for the analysis: 50 ml in plastic bottles for heavy metals, 250 ml in plastic bottles for organic parameters, and 2 L for oil and grease and total hydrocarbon.

Samples for heavy metals analysis have been filtered with 45 μm syringe filters and acidified with nitric acid. Samples were tagged with specific code and stored in a cooler bag (< 4°C) for 24 hours before delivered to an accredited laboratory in Italy.

The data from each monitoring and sampling point was recorded in field sheets, before being digitalized into Microsoft Excel spreadsheets.
Sampling waters have been taken according to tide changes ensuring the collection during the low tide in order to reduce the alteration of chemical-physical parameters due to water direction changes. The coordinates were recorded with a portable GPS (GARMIN eTrex 10 brand model) and entered into Google Earth aerial images.

Samples points:

A1: Farmington River– Poinnah Town
A2: Farmington River
A3: Owensgrove Creek
A4: Farmington River
A5: Wastewaters discharge
A6: Yor-Chu (also known as Ninpu) Creek
A7: Yor-Chu (also known as Ninpu) Creek

Water quality measurement in Farmingtone River.

[16] US EPA, Quick Guide To Drinking Water Sample Collection, 2016.

Key findings

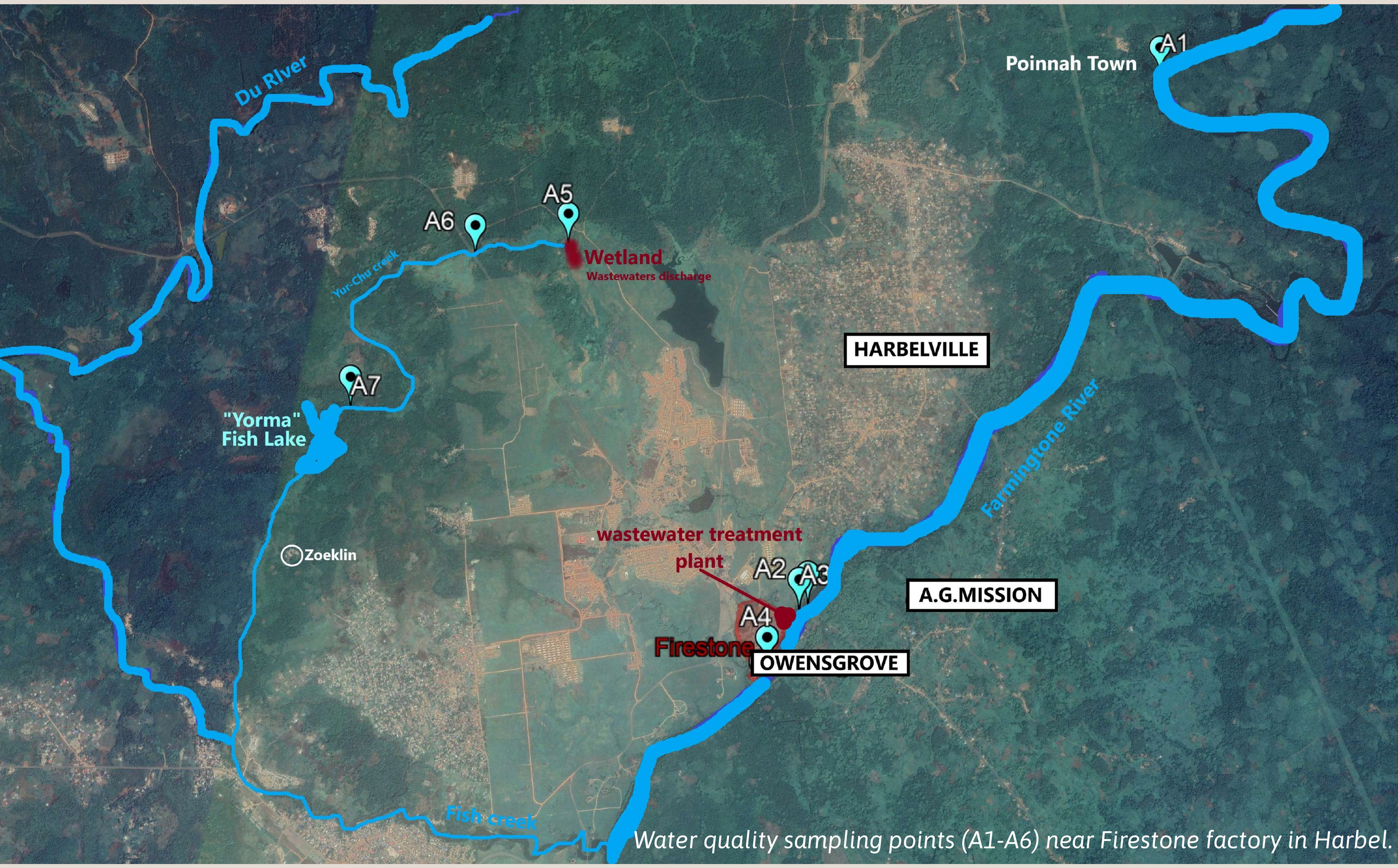
Farmington River

Liberia does not have a complete water law with fixed standards for pollution levels, so international water standards as World Health Organizations has also been used to compare results with law limits.

We found high **Total Dissolved Solids (TDS)** levels (> 1.000 mg/l) and high **conductivity (EC)** values (> 2.000 µS/cm), together with low **dissolved oxygen (OD)** concentration (below 1 mg/l), in points A2, A3, and A4, as shown in Table 1.
We found water has acidified, proceedings from the control point upstream of the Firestone plant A1 (pH 8,1) to A2 (pH 6,8) even if pH is between the permitted standard fixed by World Health Organization [17].

Parameter	A1	A2	A3	A4
pH	8,1	6,8	6,7	6,7
T (°C)	35	30,07	30,2	30,1
EC (µS/cm)	17,5	2.087	2.116	2.127
TDS (mg/L)	19,5	1.043	1.054	1.065
O.D (mg/L)	6	0,6	0,7	1,7
ORP (mV)	237	234	240	243

Table 1. Physic-chemical analysis on Farmington River.



Water quality sampling points (A1-A6) near Firestone factory in Harbel.

[17] WHO, Drinking Water quality guideline, 2008.

Iron concentrations in all the four analyzed points (A1: 0,32 mg/l; A2: 0,4 mg/l; A3: 0,69 mg/l; A4: 0,4 mg/l) are above the Liberian water quality guideline for drinking water (guideline value: 0,1 mg/l -Class I) [18] as shown in Table 2.

In Owensgrove creek (A3), which flows close to the factory, the concentration of **manganese** (0,08 mg/l) is higher than the WHO Guidelines limit (0,05 mg/l) for human consumption.

Phosphates are chemicals containing the element phosphorous, and they affect water quality by causing excessive growth of algae. We found phosphates above the Liberian water quality guideline in all four points. **Total phosphorous** concentration is upper than the US EPA level both for human consumption and water life protection in all four points in the River.
In Owensgrove creek (A3) **ammoniacal nitrogen (**a measure of the amount of ammonia, a toxic pollutant) exceeds the European Standard for human consumption, [19] and the Canadian guidelines for the Protection of Aquatic Life [20]. These international references have been used because neither Liberia EPA nor WHO have fix standards for this parameter.

BOD5 (the amount of dissolved oxygen needed by aerobic biological organisms to break down organic material present in a water sample at a certain temperature over a specific time period of 5 days) exceeds by two times the European Limit for aquatic life protection (fixed at 5 mg/l) both in Owensgrove creek (A3: 12 mg/l) and in Farmington River (A4: 11 mg/l), as shown in Table 3. European limit has been used because WHO does not include a limit for BOD5.

Total hydrocarbon in Owensgrove creek (0,56 mg/l) has been recorded above European Union guidelines fixed for drinkable water [21].

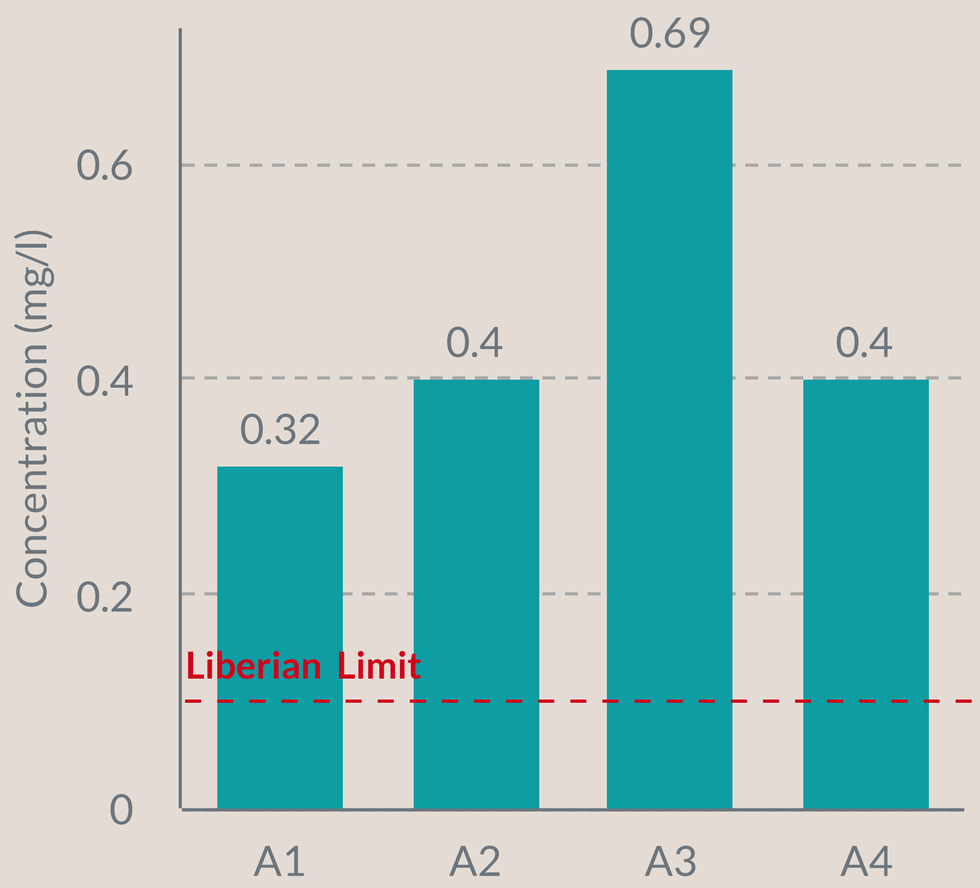


Table 2. Iron concentration in Farmington River water.

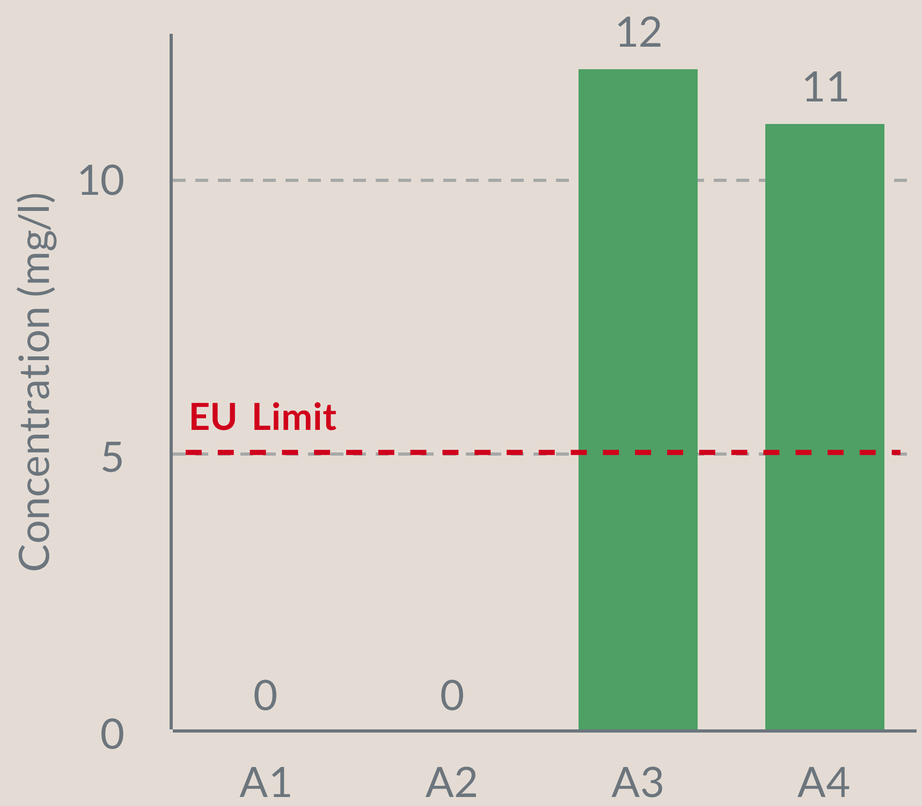
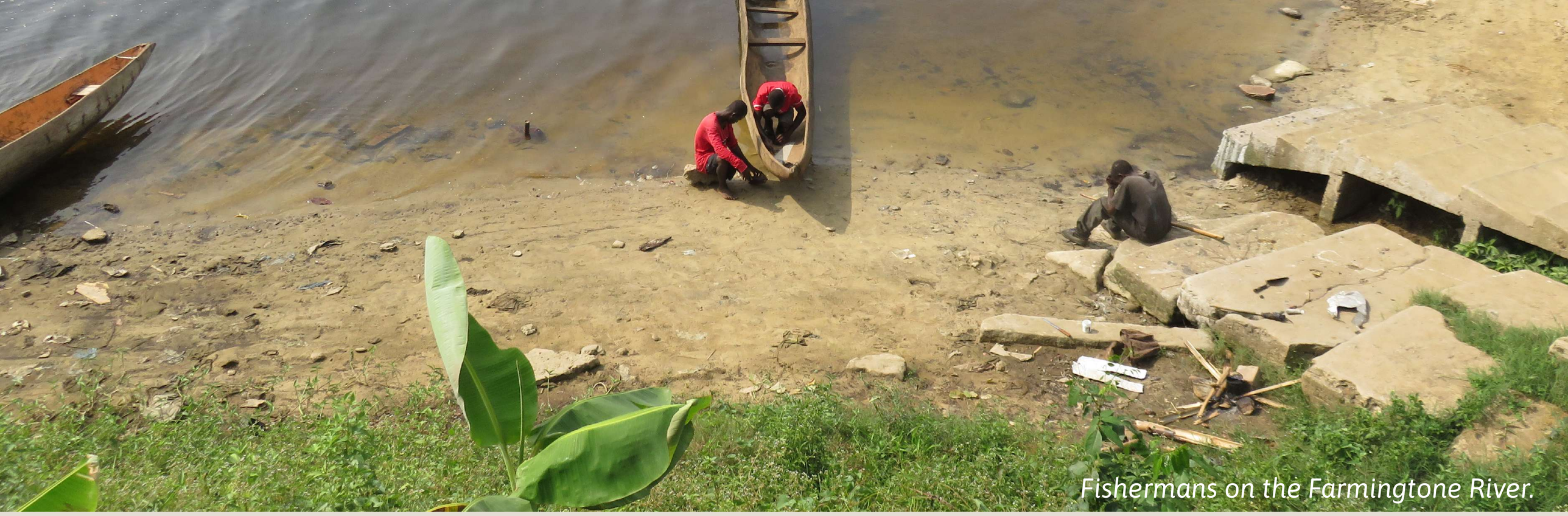


Table 3. BOD5 concentration in Farmington River water.

[18] EPA Liberia, Liberian water quality guidelines.
[19] EU Council Directive 98/83/EC, 1998. https://eur-lex.europa.eu/legal-content/IT/TXT/PDF/?uri=CELEX:31998L0083&from=EN
[20] Canadian Water Quality Guidelines for the Protection of Aquatic Life, Ammonia. http://ceqg-rcqe.ccme.ca/download/en/141
[21] Deborah Chapman, Water Quality Assessment -published on behalf of WHO, EPA, UNEP, 2016.



Fishermans on the Farmingtone River.

Wetland treatment area and Yor-Chu creek

In the **wetland treatment area** (A5), we found **aluminum** (6,3 mg/l) concentration above the WHO standard for human consumption [22] and above the US EPA aquatic life protection limit [23]. **Copper** (0,012 mg/l) concentration is above the Liberian water quality guidelines.
In the wetland treatment area, **iron** concentration (19 mg/l) was 63 times more than the control point (station A1) in the Farmington River. This level is higher than the Liberian limit (0,1 mg/l) for drinking water and the WHO standard (0,3 mg/l) for human consumption. **Manganese** concentration (0,42 mg/l) is also above the WHO standard for drinking water (0,05 mg/l).
Total phosphorous concentration (43 mg/l) is above the aquatic life protection limit set up by US EPA (0,1 mg/l). We found that p**hosphate** levels are higher than the Liberian limit. No nitrates have been found in high concentrations, but **ammoniacal nitrogen** exceeds the standard for human consumption and it decreases along the transect. In the A5 station, we found that **Biochemical oxygen demand (BOD5)** (350 mg/l) and **Chemical oxygen demand (COD)** (1.300 mg/l) exceed respectively 70 and eight times the US EPA aquatic life protection.

Yor-Chu creek (A6, A7) is used for domestic purposes by local communities and the water quality is not drinkable because of pollution.
Iron concentration levels in the Yor-Chu creek (A6 and A7) is above the Liberian limits and the WHO standard. **Manganese** is 4 times above the WHO safe level (0,05 mg/l) in point A6 (0,18 mg/l) and in point A7 (0,22 mg/l) as shown in Table 4. According to the Liberian Water Quality Guideline,[24] **phosphate** concentration in Yur-Chu creek exceeds the limit for drinking water by 540 times in A6 and by 130 times in A7, as shown in Table 5.
In station A6 **BOD5** (20 mg/l) is four times higher than the aquatic life protection limit. No high level of **COD** was recorded in the Yor-Chu creek.

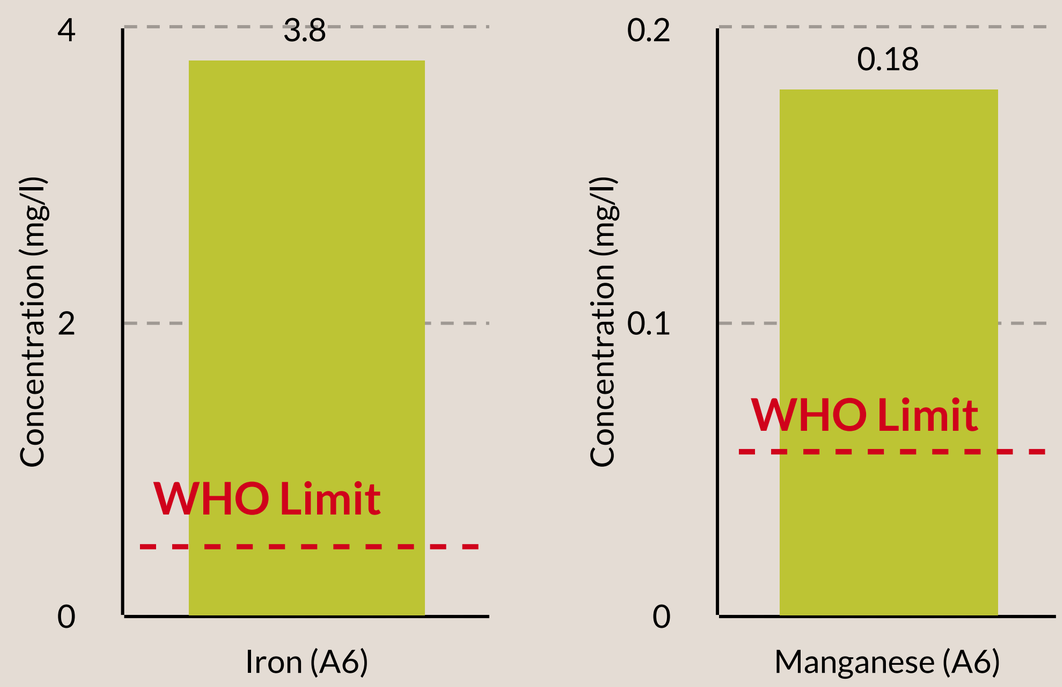


Table 4. Iron and manganese in Yor-Chu creek (A6).

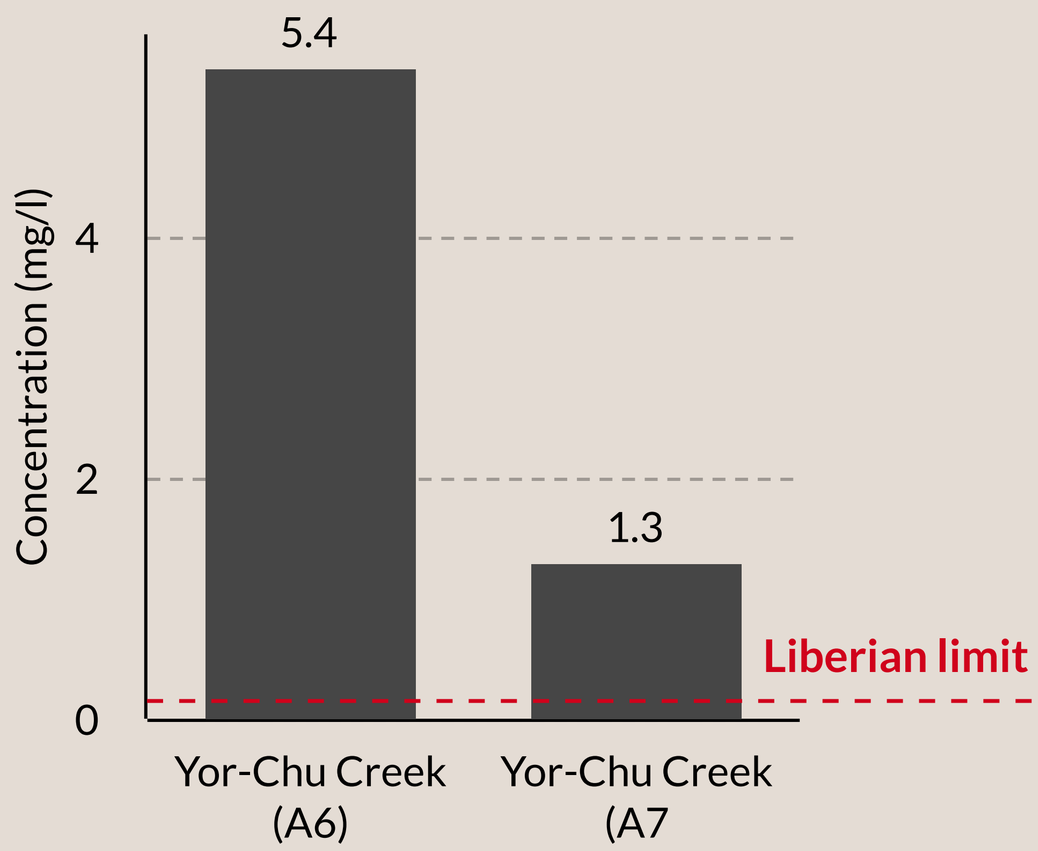


Table 5. Phosphates concentration in the wetland area (A5) and in the Yor-Chu creek (A6).

[22] WHO; Water Sanitation Health. https://www.who.int/water_sanitation_health/resourcesquality/wqachapter3.pdf
[23] US EPA; Aquatic Life Protection criteria. https://www.epa.gov/wqc/national-recommended-water-quality-criteria-aquatic-life-criteria-table
[24] EPA Liberia, Liberian water quality guidelines.

Final Discussion

The environmental data we collected revealed significant changes in the water quality of the **Farmington River** between the control point (A1) near Poinnah Town and the downstream stations (A2, A3, A4) near the Firestone plant.
Downstream stations near the Firestone factory confirm **water quality parameters above the national and international permissible limits for human consumption and for aquatic life protection. Hence we found the water is severely polluted.**
Our findings suggest that the health of thousands of people that access the Farmington River for their daily subsistence activities is therefore in danger.
Furthermore, high concentrations of pollutants threaten the freshwater ecosystem of the Farmington River that provides habitat for flora and fauna that represent goods and services for local communities such as Owensgrove, A.G.Mission, Zangar Town, Cotton Tree, and others.

The investigation shows important differences in the water quality between the **wetland** water treatment area and **Yor-Chu creek**. The Yur-Chu creek's stations show pollution caused by the rubber factory. Pollutants are then diluted moving away from the direct discharge point (A5) to the creek (A6-A7).
Based on our analytical data, it seems that the **Firestone rubber factory is responsible for high concentrations of heavy metals in the wetland area** (A5).

These results suggest that the **wastewater treatment system** (first and second generation) **is not working as planned, posing a significant danger to the public health of affected local communities.** The system is not able to control and/or reduce contaminants to an acceptable local and international standard level, and it is releasing high levels of harmful and toxic pollutants into the environment with severe consequences for the health of local people.

Besides drinking, human populations use water for hygiene purposes (e.g. washing) and recreation (e.g. swimming and boating). Such activities have an associated health hazard if the water is polluted due to the risk of ingestion and skin contact. Irrigation of food crops and water to farmed animals (such as goats and hens) with polluted water represents a possible health risk to food consumers, particularly with respect to residual toxic compounds like heavy metals.

Many communities live close to creeks and rivers that are potentially impacted by wastewater discharge from the wetland (mainly during the rainy season because of flood events). Communities as Kpanyah Town, Brown Town, Mazoe Town, Zoeklin, Dolo Town and others depend from these water resources for their daily life.

Water pollution in Yor-Chu creek.

Air quality assessment

The background

During the manufacturing and storage of rubber products, various gases, vapours, fumes, and aerosols are emitted due to the leaching of chemicals during the vulcanization, coagulation, and wastewater discharge. The rubber industry releases large amounts of hazardous compounds into the air including *Polycyclic Aromatic Hydrocarbons* (PAH) and *Volatile Organic Compounds* (VOCs) that are further linked with odour annoyance. During the processing of latex, *hydrogen sulphide* and *ammonia* are also added to latex and are responsible for the smell. The smell is produced during coagulation, drying process, and by wastewaters [25].

The smoking step to dry rubber sheets produces *particulate matter* (generally known as PM10) - inhalable particles with diameters that are 10 micrometres and smaller - that represents a health problem in the workspace and also it contributes to outdoor air pollution [26].

According to the Firestone's Environmental Impact Assessment (EIA), air pollution is mostly linked with *Volatile Organic Compounds* from wastewater treatment plant. Moreover, they affirmed that wastewaters are responsible for *odours* formation and one of the most common odours as “rotten eggs” smell of *hydrogen sulphide* [27].

The methodology

The objective of air monitoring was to estimate the quantity of the suspended outdoor dust (Particulate Matter - PM10 and PM2.5), through daily measurements, as well as the concentration of outdoor total Volatile Organic Compounds (TVOCs) and outdoor odour. Furthermore, the amount of ammonia and hydrogen sulphide in outdoor air was recorded through passive samplers.

SOURCE INTERNATIONAL carried out air monitoring between February the 23rd and March the 1st 2020; during the dry season.
The air monitoring was designed taking into account the wind direction, observed prevailing wind from North to South during the morning and South-West to North-East during the afternoon [28].

Firestone plant and its installations.

[25] Santosh Jagadale et al., Environmental Concern of Pollution in Rubber, 2015.
Industry, https://www.researchgate.net/publication/316510935_ENVIRONMENTAL_CONCERN_OF_POLLUTION_IN_RUBBER_INDUSTRY
[26] P. Tekasakul, Surajit Tekasakul et al., Environmental Problems related to Natural Rubber Production in Thailand, 2006.
[27] Liberian Environmental Services INC, EIA for wastewaters facility, 2008.
[28] Wind Finder App, https://it.windfinder.com/#3/49.5042/9.5421

Key findings

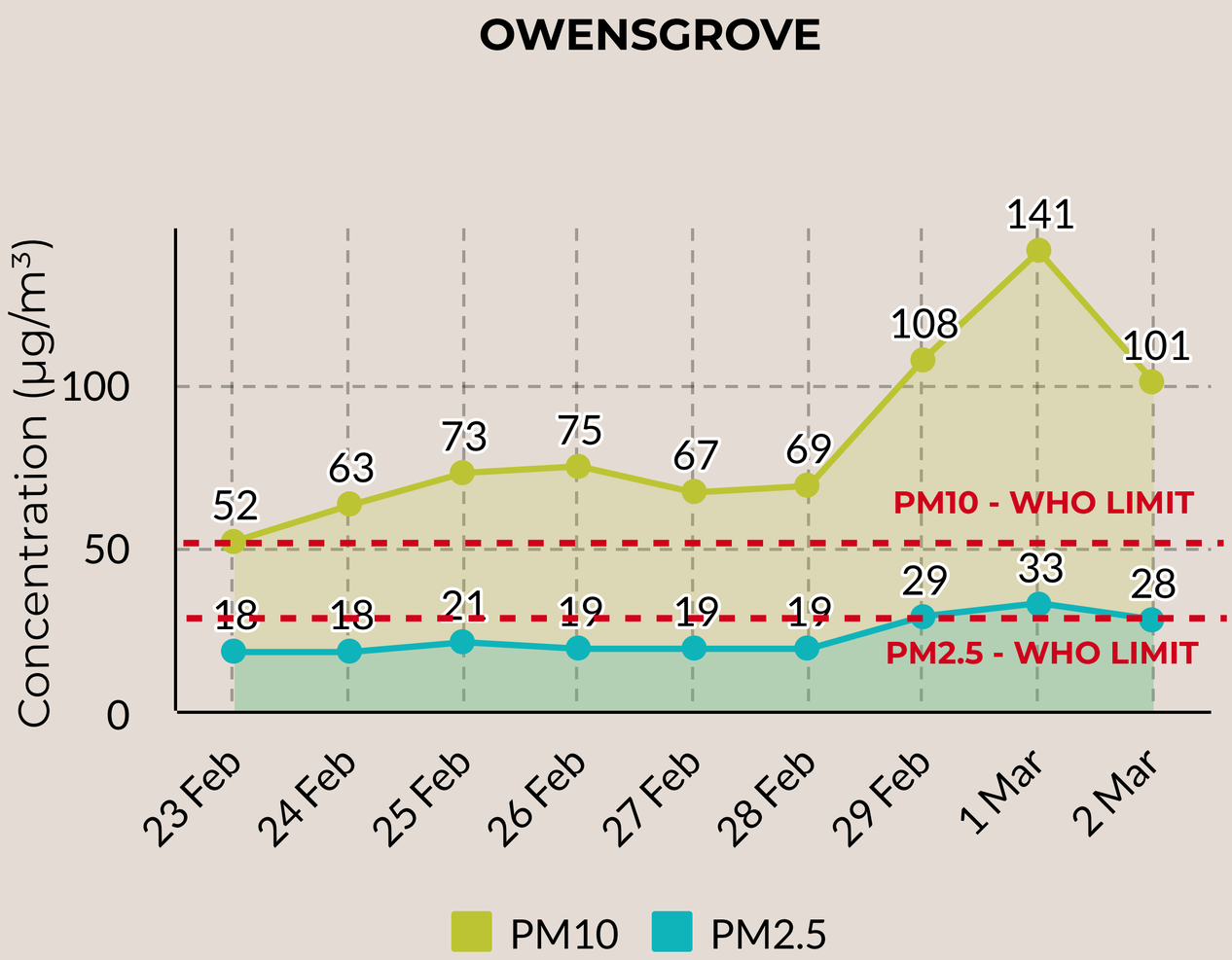
Inhalable dust

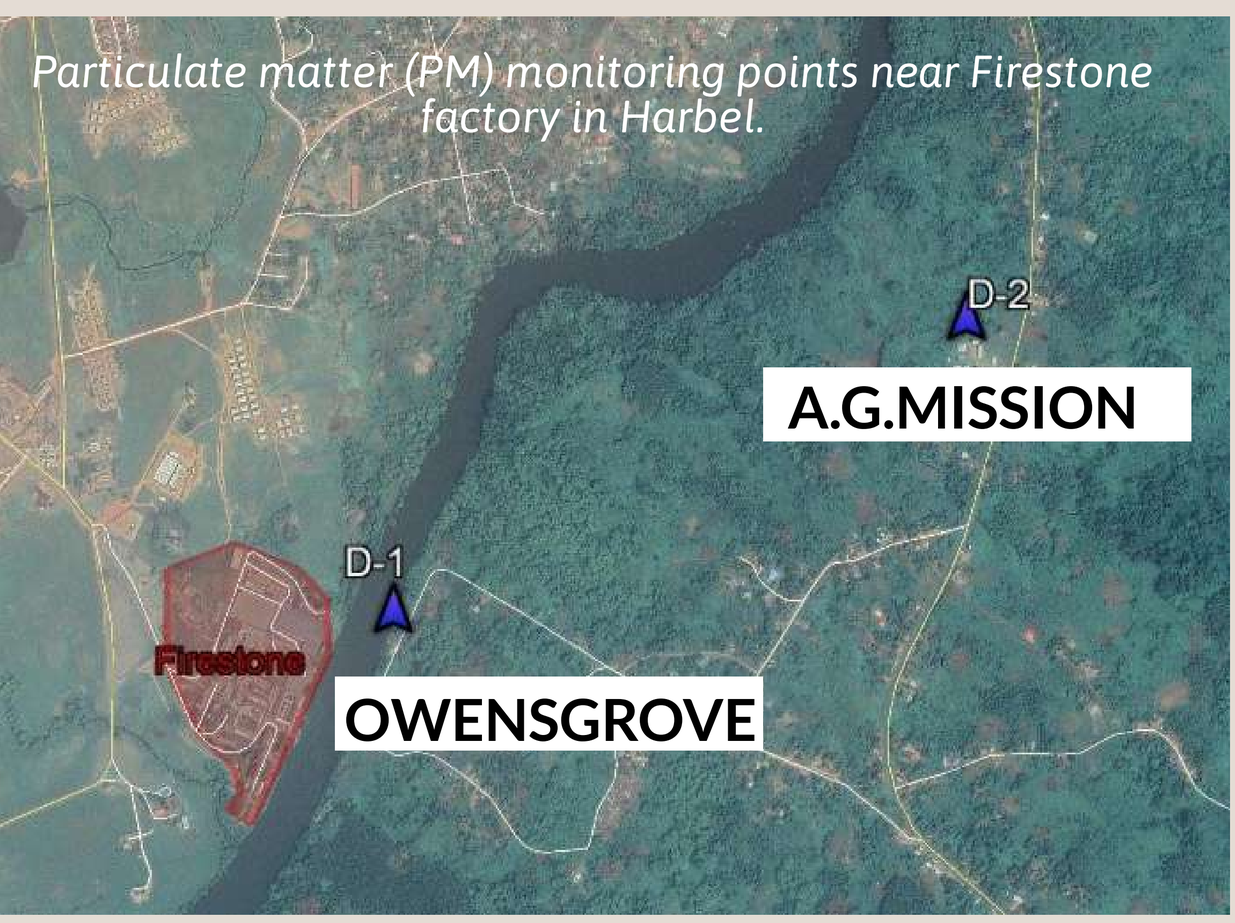
Two stations for dust monitoring have installed in two communities.
***Station D1* – Owensgrove community** is located in front of the Firestone factory on the east side of the Farmington River, approximately 140 meters far. This station aims to measure the alleged impact on air quality due to the combustion and drying activities in the different factory divisions.
***Station D2* – A.G. Mission** is located in the north-east of the factory, approximately 2 Km from it, near the bridge that connects to Harbelville. This point has been chosen as a reference point.

To quantify the 24 hours concentrations of breathable particulate matter PM10 and the finest one PM2.5 in the air, we used 2 portable instruments AEROQUAL S500 model. These instruments have been tested by international institutions such as the United States EPA and the New York Department of Environmental Protection [29].
According to ISO international guidelines for air quality measurements, they have been installed at no more than two meters from the ground [30].
The Liberia EPA was not able to share with us (March 2020) the Air Quality regulations which are still under validation, so we used the international guidelines of WHO as reference.

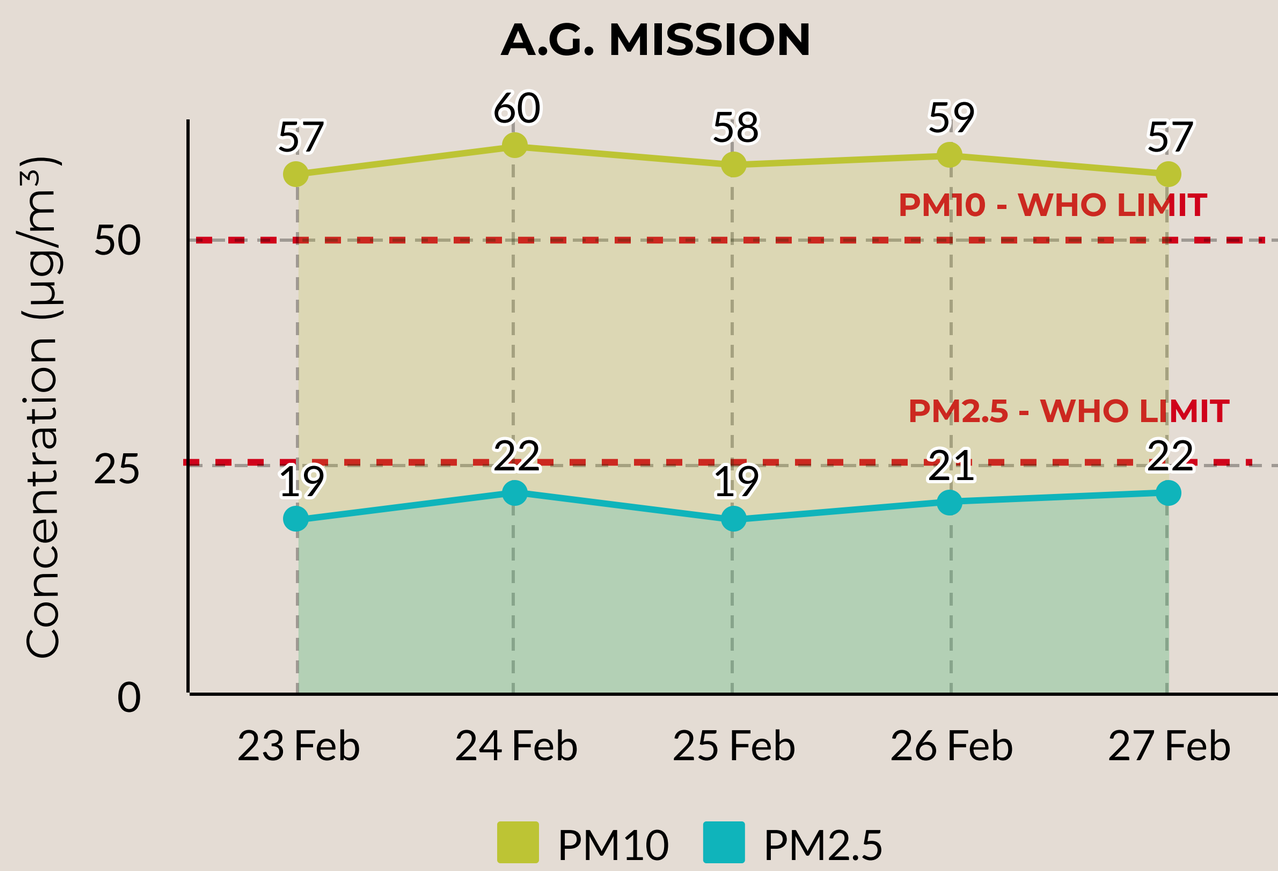
Comparing results from these different stations (D1 and D2), we observe a **higher concentration of PM10 - PM2.5 in D1-Owensgrove station**, probably linked with the vicinity to the factory.

The 8-days PM10 monitoring shows a daily average of 83 µg/m³ in Owensgrove and 58 µg/m³ in A.G. Mission.
Within 8 days of 24-hour records, the maximum PM10 limits set by WHO were exceeded every day at the Owensgrove station. We found **PM10 daily average concentration in Owensgrove is 43% higher than A.G. Mission.** For fine particulate **PM2.5, daily concentrations exceed the WHO limit for three days in Owensgrove station**; no level above the limit of PM2.5 has been recorded in A.G. Mission.
PM10 is generally associated with wood combustion that in the factory is used in the drying process.





Particulate matter (PM) monitoring points near Firestone factory in Harbel.



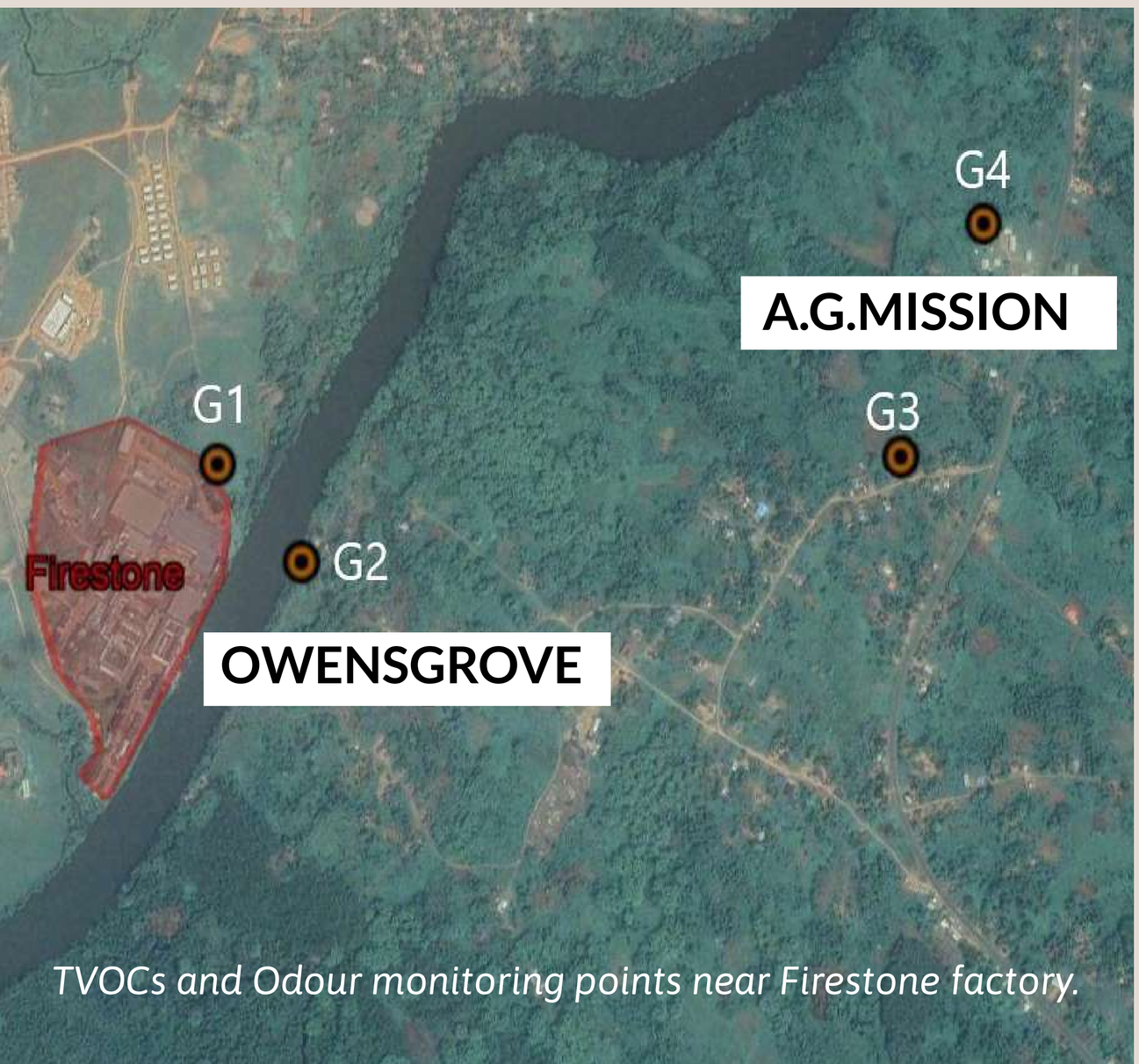
[29] Aeroqual, U.S. EPA and Aeroqual will work together for low cost air quality sensor future. https://www.aeroqual.com/us-epa-and-aeroqual-will-work-together
[30]ISO 9359:1989 Air quality, Stratified sampling method for assessment of ambient air quality.

Total Volatile Organic Compounds (TVOCs) and Odour

Volatile organic compounds (VOCs) are emitted as gases from certain solids or liquids. VOCs include a variety of chemicals, some of which may have short- and long-term adverse health effects. The total volatile organic compounds (TVOCs) that are further linked with outdoor odour annoyance have been recorded in four locations:

G1 - Firestone Factory: around the factory perimeter on the north side of the facility at Harbel
G2 - Owensgrove: 140 meters in front of the Firestone factory
G3 - Owensgrove clinic: 1 Km north-east from the Firestone factory
G4 - A.G. Mission: 1,7 Km north-east from the Firestone factory chosen as a control point

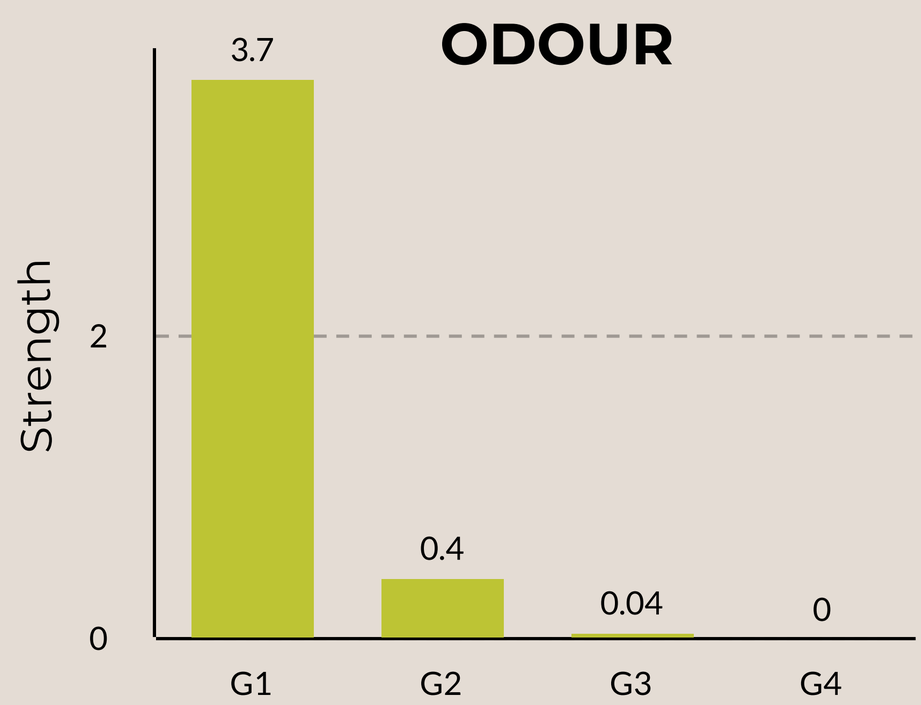
We measured total VOCs through a portable instrument AEROQUAL S500 based on photo-ionization detection (PID) with a 0-20 ppm resolution level.
Odours were recorded using a handheld odour monitor Sensigent OMX-SRM that works indicating a relative value by comparing odour to purified air and measuring odour strength. Strength refers to the intensity or magnitude of the odour sensation. It increases as a function of concentration. Odour is a dimensionless measurement.
TVOCs and odour's data have been acquired for short sessions of 15-30 minutes each, through measurements taken every minute for TVOCs, and every second for odour between February the 25th and March the 1st 2020.

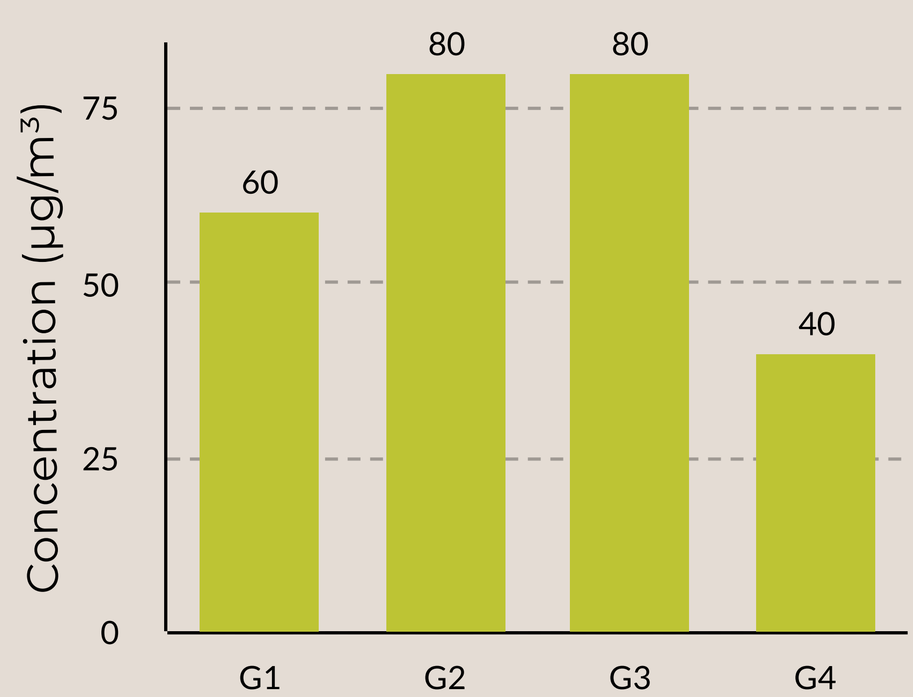


TVOCs and Odour monitoring points near Firestone factory.

Odour strength varies greatly among the four stations: **the highest value has been recorded close to the Firestone factory:** 3,70 average value with a maximum peak of 58,35.
No perceptible odours (average valueclose to zero)have been recorded by the instrument in A.G. Mission. These air quality measures revealed how the **Firestone factory contributes to the odour annoyance that is strongly perceived by local communities** and that has been reported very often by community members as one of their major concerns [31].

TVOCs concentrations are higher in the stations close to the Firestone factory and surrounding areas, and they decrease moving far from the source of pollution. The average value range in Owensgrove is 80 µg/m^3, compared with 40 µg/m^3 in A.G. Mission. The difference in TVOCs between the control point (G4) and the exposed areas (G1-G2-G3) is considered to reflect **contributions from the Firestone's factory** as all the other factors (road, burning charcoal for cooking, traffic) are very similar in all points. No international guidelines are fixed for outdoor TVOCs.





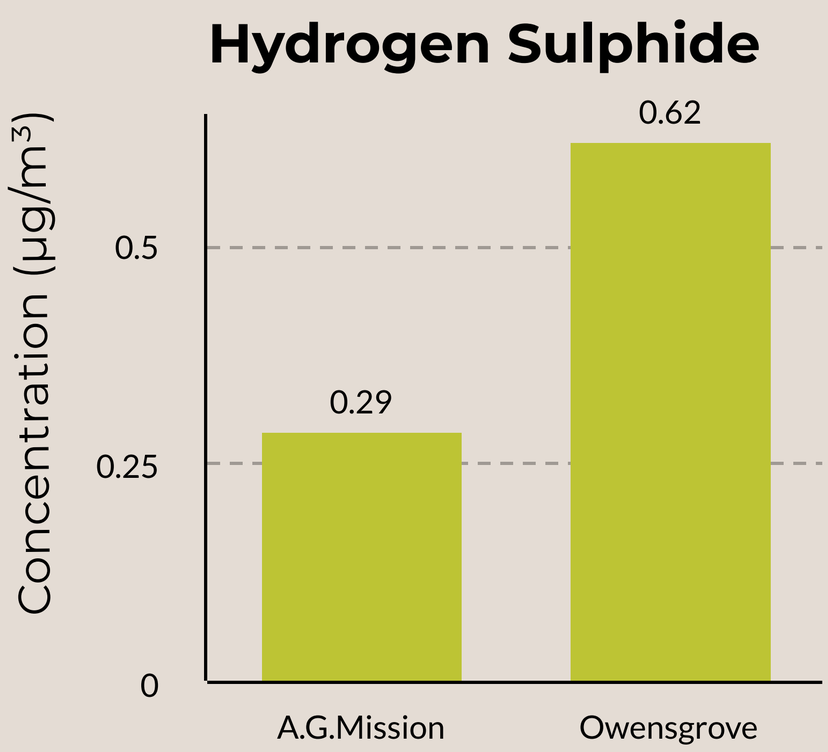
Ammonia and Hydrogen Sulphide

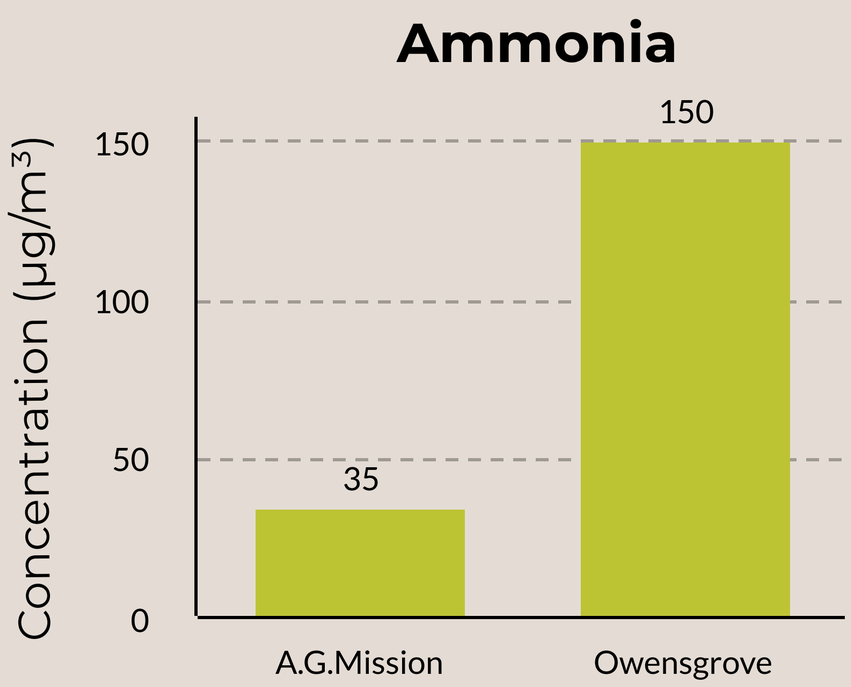
Ammonia and sulphuric acid are used during coagulation and cleaning processes. Moreover, during wastewater discharge and drying process they are released into the atmosphere.
Ammonia exposure is linked with chronic effects reported in humans include reduction in pulmonary function, cough, phlegm, wheeze, and dyspnea [32]. Hydrogen sulfide is both an irritant and a chemical asphyxiant with effects on both oxygen utilization and the central nervous system [33].
For the outdoor air quality measures, two fixed stations have been used to assess these gases concentrations at different distance from the factory: in Owensgrove (station R1) and A.G. Mission (station R2).

Gases have been sampled through a sampler called Radiello® patented by the Foundation Salvatore Maugeri (FSM) and it is based on a diffusive sampling process using a chemical absorbent cartridge.
Samplers were put on house's walls under their own box with a roof to protect them from potential rain and animals; according with the ISO international guideline for air quality measurement, they have been installed at no more than two meters from the ground [34].
The cartridges have been put in place for 8 days for Station R1 (from February the 23rd to March the 2nd) and 7 days for Station R2 (from February 24th to March the 2nd). Blank values have been also taken for laboratory. Basic meteorological parameters were recorded: temperature varied between 30-35°C, humidity between 75-90%, and wind velocity was less than 10 Km/s.
After the sampling period, absorbents have been stored in a special clean plastic tube in a cooler bag until the deliver to the laboratory in Italy.

Gases monitoring points neat Firestone factory in Harbel.

Hydrogen sulphide concentrations were much higher in Owensgrove (0.62 µg/m³) then in A.G. Mission (0.29 µg/m³) on a weekly average time. Moving far from the factory the hydrogen sulphide concentration drastically reduced. However, these concentrations are lower than the WHO international standard (150 µg/m³ during 24 hours).
Weekly ammonia concentration also showed a difference between the two monitoring stations: **ammonia concentration measured in Owensgrove (150 µg/m³) is more than 4 times the concentration of the same compound in A.G. Mission (35 µg/m³).**
However, these concentrations are lower than the Canadian air standard taken as reference (1400 µg/m³ during 1 hours).
Some factors contribute to the underestimation of the measure: high air humidity (75-85%) influence the fall-down process of gases, reducing their concentration in the air.
Hence, we can suggest that the Firestone **factory is responsible for ammonia and hydrogen sulphide emissions into the air,** even if they are lower than the international limits used.





[31] UNDP, Human Rights in Liberia's Rubber Plantations: Tapping into the Future, Monrovia 2006. https://www.refworld.org/pdfid/473dade10.pdf
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Final Discussion

Our air quality investigation demonstrates higher pollutant levels in the vicinity of the Firestone factory in Harbel. Air pollutants include gases as ammonia and hydrogen sulphide, particulate matter (mostly PM10), total volatile organic compounds (TVOCs), and odour.
The quality of all these parameters gets worst as they get closer to the Firestone factory. Given the rural context of the investigated area, the main source of those pollutants are most likely to be the Firestone's facilities.

Both PM10 and PM2.5 are pollutants inhalable particles very harmful for human health [35]. They are dangerous for exposure for both short periods (hours, days) or longer ones (months, years). Risk associated to high concentration of PM10 and PM2.5 include respiratory and cardiovascular diseases, aggravation of asthma and respiratory symptoms and various forms of lung cancer [36].

Although the **odour annoyance** is not classified under toxic fumes, several studies have suggested that those exposed to such emissions may lead to **shortness of breath, eye irritation, headache, loss of appetite, and dry throat, which can also lead to psychological stress** [37], [38]. Strong odours may cause some people to feel a burning sensation that leads to coughing, wheezing or other breathing problems. People who smell strong odours may get headaches or feel dizzy or nauseous.

Young children, the elderly, and pregnant women may be more sensitive to odours [39].

Total Volatile Organic Compounds (TVOCs) are very harmful to humans because they affect the nervous system and they are carcinogenic and mutagenic agents [40],[41] Health effects may include:
•Eye, nose and throat irritation, dyspnoea;
•Headaches, loss of coordination, nausea, fatigue;
•Damages to liver, kidney and central nervous system;
•Allergic skin reaction [42].

Hydrogen sulphide is both an irritant and a chemical asphyxiant with effects on both oxygen utilization and the central nervous system. Low concentrations irritate the eyes, nose, throat, and respiratory system. Repeated or prolonged exposures to high concentrations may cause eye inflammation, headache, fatigue, irritability, insomnia, digestive disturbances, and weight loss [43].
Ammonia is a colorless highly irritating gas with a sharp suffocating odor.
Exposure to high levels of ammonia in air may be irritating to your skin, eyes, throat, and lungs and cause coughing and burns [44].

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2015. https://www.researchgate.net/publication/316510935_ENVIRONMENTAL_CONCERN_OF_POLLUTION_IN_RUBBER_INDUSTRY
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CONCLUSION

This environmental investigation represents the first independent and open-access study that informs and tracks the actual water and air pollution in the Firestone factory and plantation area.
The study suggests different levels of pollution and environmental impacts attributable to the Firestone Rubber Factory activities located in Harbel.

High water pollution levels in the wetland treatment area and in Yor-Chu creek is harmful to people exposed to and ecosystems. Heavy metals such as iron and manganese in Yor-Chu creek are above the Liberian water quality guideline and also the WHO drinking safe level. Phosphate concentration in Yur-Chu creek exceeds the limit for drinking water by 540 times. We found an important level of pollution in the wetland area, where the Biochemical Oxygen Demand (BOD5) and Chemical Oxygen Demand (COD) exceed respectively 70 and eight times the US EPA aquatic life protection limit.
The study demonstrates the increase of some pollutants along the course of the Farmington River. The bad quality of the water of the Farmington River can compromise the health of people who lives along with it and that depends on the river for their subsistence.
Wastewater discharges from the rubber industry into the environment can cause serious and prolong consequences on communities' health and livelihood. Women are particularly affected by the loss of access to safe water, as they are responsible for feeding and take care of their families and they are generally in charge of providing water to their families and communities.

Higher pollution of air has been recorded in the vicinity of the Firestone factory.
In the community of Owensgrove significant inhalable particulate matter, PM10, concentrations, above the standard of international guidelines, have been measured during all eight days of monitoring.
Volatile Organic Compounds' average value in the Owensgrove community is double compared with the background zone in the A.G. Mission community, located at 1,7 Km at the north-east of the Firestone factory.
We found the highest odours strength close to the Firestone factory perimeter: as we move away from the factory, odour magnitude decreases significantly.
In Owensgrove, ammonia and hydrogen sulphide concentrations in the air are four and two times higher than the background area of A.G. Mission respectively, although they remain under international standards.

We consider that the lack of control of the national government (under the EPA) on the enforcement of environmental standards, led to company neglect their obligations towards environmental protection and health and pollution prevention.
Furthermore, national environmental laws are weak: some environmental regulations are not in place (as air quality guidelines) and some others are not totally complete in environmental standards (as the water quality guidelines). In this legal lack, environmental protection and human health are extremely at risk.

Even if Liberia's constitution (1986) does not mention the protection of the environment nor the right to water Liberia has signed (1967) and ratified (2004) both the International Covenant on Economic, Social and Cultural Rights and the International Covenant on Civil and Political Rights and therefore it has the obligation to respect the right to life, the right to health, the right to food, the right to water and the right to live in a clean and safe environment.
The levels of pollution that we recorded in this study are a clear threat to those rights and the State of Liberia should act very soon to protect the right of its citizens.

RECOMMENDATIONS

Firestone and parent company Bridgestone should:

- Remediate urgently the environmental damages they provoked across the years through a detailed plan of concrete and fast actions.
- Urgently ensure access to drinkable water to all the affected communities, taking into consideration that deeper wells can be affected by salinity intrusions.
- Provide an indemnification to those people who lost their livelihood because of their pollution, including odour.
- Improve the wastewaters treatment plant near Kpanyah Town and keep constant maintenance in order to reduce the pollution caused by their facilities.
- Apply innovative technologies to contain and/or prevent air pollution.
- Steadily monitor their activities impacts through air and water quality monitoring.
- Share publicly environmental assessment results and their regual water test findings to all stakeholders: EPA, Ministry of Health, Ministry of Mines and Energy, Civil Society Organizations, and local communities.
- Proper inform and train workers about health potential risk, and provide them with base DPI on the workplace.
- Monitor workers' exposition to harmful gases as ammonia and hydrogen sulphide in workplaces.
- Set up an independent multistakeholder task force to investigate and remediate our findings

The **Government** should:

- Promote the development of a proper Environment Ministry to specifically address natural resources protection and right management, releasing it from the Ministry of Mines and Energy.
- Establish national regulations on water and air quality specific for the rubber industry.
- Guarantee transparency on environmental regulations.
- Strengthen laws ensuring transparency and public participation with the affected population by the company's activities.
- Implement dispositions to manage the emergency state of the socio-environmental-health situation in the studied area.
- Implement specific policies for marginalized and vulnerable groups.
- Reinforcing the linkages between human rights and the environment.
- Ensure an adequate health care attention to affected communities.

The **Environmental Protection Agency** should:

- Undertake an immediate assessment of the environmental impact of rubber production and processing.
- Providing high-quality public information and advising local communities on the state of the environment.
- Guarantee the rule of law for water and air pollution.

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