INTERNATIONAL JOURNAL OF MULTIDISCIPLINARY: APPLIED BUSINESS AND EDUCATION RESEARCH
2024, Vol. 5, No. 10, 3951 – 3967
http://dx.doi.org/10.11594/ijmaber.05.10.14

Research Article

A Biochar-Based Water Treatment System for Barangay Sawmill, Villaverde, Nueva Vizcaya

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Article history:
Submission 31 September 2024
Revised 07 October 2024
Accepted 23 October 2024

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ABSTRACT

A comprehensive evaluation was carried out aiming to address water quality issues in Villaverde, Nueva Vizcaya. The research focused on designing and appraising a Biochar-Based Water Treatment System. This review was performed hoping to meet the urgent need for supplying potable water free of contaminants, especially during periods of elevated murkiness caused by heavy precipitation. The foundation of the system relies on utilizing biochar, specifically crafted from coconut husks. This particular biochar is renowned for its remarkable absorptive properties. A treatment system with a flow rate of 250 mL per minute was built using a systematic design process. The efficacy of this system underwent thorough testing, including examining both physical traits and bacteriological integrity. Findings revealed a statistically significant enhancement in water transparency and reduction of microbiological dangers, notably when flow rates were lower. Economic assessments, like breakeven analysis and Benefit-to-Cost ratio, further substantiated the system's feasibility. Over 48 months, it is anticipated the system would recoup initial setup expenses and ongoing operational costs, thus offering a viable and cost-effective choice for the community. Results indicate the Biochar-Based Water Treatment System has ability to supply safe drinking water and provides substantial economic benefits. This system embodies a crucial advancement towards achieving sustainable water management in the Villaverde municipality.

Keywords*: Biochar, Water Treatment, Economic Viability, Coconut Shell Charcoal*

How to cite:
Rodolfo, J. S. & Nebrida, A. P. (2024). A Biochar-Based Water Treatment System for Barangay Sawmill, Villaverde, Nueva Vizcaya. *International Journal of Multidisciplinary: Applied Business and Education Research*. *5*(10), 3951 – 3967. doi: 10.11594/ijmaber.05.10.14

Introduction

The concept of "potable water" implies fluids suitable for human intake, a diminishing global asset experiencing escalating shortages. Growing international freshwater demands impose difficulties on supplies, enabling various contaminants risking the safety and appeal of drinking fluids (Fluencecorp, 2019). When delivering water to clients, crucial standards concerning chemical, biological, and physical qualities must be satisfied (De Zuane, 1997). Contaminated fluids can propagate several sicknesses for instance diarrhea, cholera, dysentery, typhoid, and polio. Around 485,000 deaths per annum are thought to derive from diarrheal diseases blamed on polluted drinking fluids. Projections anticipate over half of humanity inhabiting areas undergoing water strain by 2025. Data from the World Health Organization (2019) indicates healthcare sites in poorest regions frequently lack fundamental infrastructure, specifically 22% absence access to fluids, 21% lack suitable sanitation, and 22% lack adequate waste management.

Efforts now aim to boost food yields and advance novel renewable technologies. However, water has long been overlooked, especially regarding waste disposal. A shift is needed from routine cleanup and dumping towards reuse, recycling, and recovering assets. Scarcity and pollution from unchecked discharge indicate the need for altered strategies. Recognizing wastewater's potential to enable circular economies enhances sustainability greatly. Rather than trash, it can address escalating demand in swelling cities, bolster energy production and industries, and back eco-friendly agriculture. This approach mitigates health and environmental damage from current handling. Abhisbek rightly noted in 2020 how treatment plays a key function in achieving sustainability by addressing goals like water, nutrient, and energy restoration. It is thus deemed an important step towards a greener future.

The life-sustaining qualities of water cannot be overstated, for without it organisms face deleterious effects such as dehydration. No body can properly function without this essential element, as water regulates temperature, nourishes every cell and maintains hydration across all tissues and organs. It also cushions joints as a lubricant, supporting overall physiological processes. Regular intake yields a myriad of health perks too, like improved cardiovascular performance per CDC standards. The heart endlessly circulates blood through over two thousand liters daily, a nonstop process the body's water content aid. Staying properly hydrated supports this crucial cardiovascular role by facilitating enhanced function. Optimal hydration exceeding losses even improves muscular operation throughout the form, with cardiac abilities better promoting strength across the body according to recent research. In summary, daily water consumption according to guidelines protects numerous systems and advantages general well-being, highlighting H2O's importance for viability.

Water processing involves an intricate system incorporating various activities including physical, chemical, biochemical, and biological methods. The main objective aims to eliminate or decrease unwanted contaminants and qualities within water. This system targets obtaining water maintaining characteristics suitable for its planned usage. Therefore, the water processing methodology varies relying on incoming water properties and intended application. The importance of water treatment has grown because of limited drinkable water and expanding worldwide population. According to Acciona studies in 2021, a meager 2.5 percent of worldwide water reserves constitute freshwater, with a minuscule 0.4 percent portion suitable for human use. Meanwhile, population increases have exacerbated pressure on water sources. Water treatment faces challenges to satisfy growing needs yet minimize environmental impact. Further innovation seeks methods improving sustainability and accessibility of the world's most critical resource.

Methodology

The Research Design

The researcher conceptualized the design and specifications of the Water Treatment System using the Product Development Method (PDM). Product fabrication entails either assembling or building a product. PDM provides the researcher with an easy method of looking at the process, which begins with idea generation and progresses to the development of specific features, then to full product development, and lastly to product testing. Any discovered flaws will be addressed, and the system will be disassembled and reassembled until it is judged to be functional and acceptable. The Water Treatment System will be manufactured, and the pieces will be assembled following the design.

Conceptual Framework

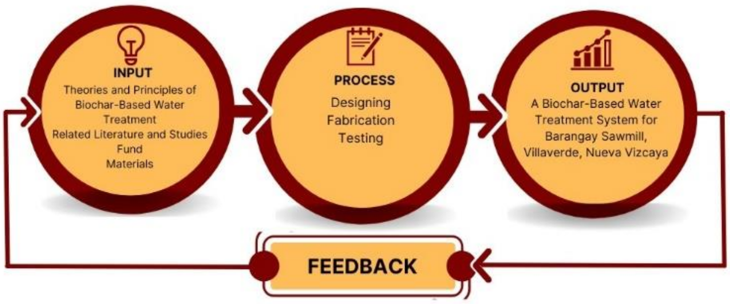

Figure 1. Conceptual Framework

As Figure 1 shows, a cyclical process leverages agricultural and forestry byproducts through pyrolysis to generate biochar for filtering polluted streams and springs. Raw materials and local water quality standards define the inputs, while comprehensive system design, configuration, monitoring and iterative feedback with residents ensure outputs meet shifting community requirements over time.

Notably, biochar production through pyrolysis transforms inputs into a medium precisely tailored for water treatment. Continuous engagement also builds ownership as the system openly incorporates changing village priorities. Most significantly, though, is that clean drinking water results from this cooperative approach - water purified through biochar immediately addresses health while establishing a model of community self-sufficiency. Regular reporting further reinforces a sustainable cycle of assessment and improvement, confirming this paradigm empowers residents as both beneficiaries and participants in local problem-solving.

In closing, this integrated framework holistically addresses Sawmill Village's water access through environmentally-sound application of indigenous resources. By prioritizing participatory design and ongoing dialog, it exemplifies how adapting technology to local contexts nurtures community well-being, responsibility and resilience in ways more top-down solutions cannot.

Process Flowchart

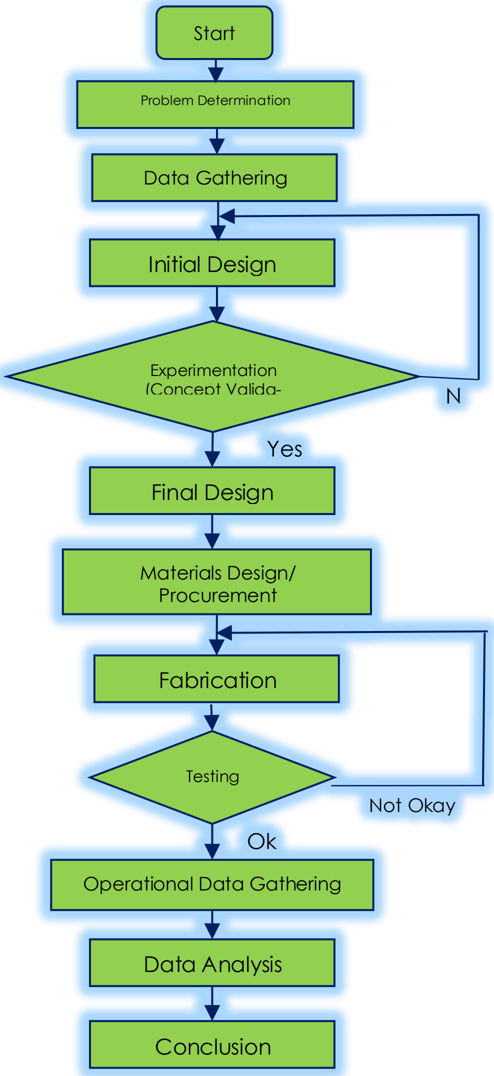

Figure 2. Project Flow Chart

Figure 2 illustrates the methodology underpinning the eco-friendly Biochar-Based Water Treatment System as a pragmatic approach to tackling water quality issues. The process commences by pinpointing the problem and gathering pertinent facts. A preliminary design is then conceived and experimentally validated. Provided the idea proves sound, it moves forward to the definitive design stage involving procurement of materials and system construction. Comprehensive testing subsequently assesses adherence to performance baselines, and satisfaction heralds the data compilation phase from operational implementation. This step is imperative to guarantee envisioned functionality when reality sets in. Post-analysis of acquired numbers guides any refinements demanded by evaluations of the system's effectiveness. Iterative testing and documentation may persist until goals are satisfactorily fulfilled, culminating in appraisal of the system's overall impact and whether objectives were realized.

Initial Testing Conducted

Before starting the design process, the researcher carried out initial tests. These tests involved experiments on small-scale water filtration systems, forming the basis for the design of the system. The outcomes of these tests will be incorporated into the design of the water treatment system.

Experimentation with Small Filtration System

The pressing necessity to remedy the water quality issues stemming from the spring in Barangay Sawmill necessitated a thorough investigation of alternative solutions. Recognizing the urgency of the situation, the researcher embarked on an empirical study, crafting a compact filtering contraption as illustrated in Figure 3. The present endeavor was not undertaken independently; it was influenced by prior research conducted by Guan et al. (2020), which similarly displayed a comparable arrangement and its efficacy.

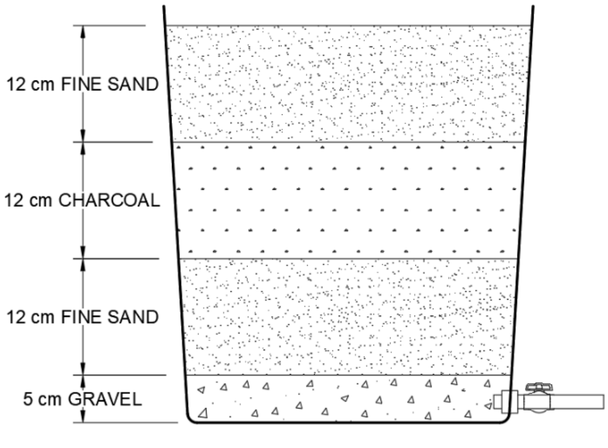

Figure 3. Small Water Filtration System

While compact in scale, the design of the filtration system was implemented with great attention to nuance. Figure 3 provides an all-encompassing depiction of the various parts through a cross-sectional rendering. Commencing from the bottommost layer, the technique initially utilizes a bed of gravel measuring 5 cm in thickness. Gravel plays a pivotal role in the filtration process by effectively removing larger particulate matter and sediment owing to its coarse texture. Subsequently, a layer of 12 cm thickness comprising fine sand is incorporated, acting as an auxiliary filtration mechanism to capture any minute contaminants that may have circumvented the preceding layer of gravel. The employment of sand filtration has been a well-established approach in the field of water purification, renowned for its ability to effectively eliminate a wide array of impurities, including some diseases.

At the core of the system's arrangement is a 12 cm stratum of charcoal, sourced solely from Mahogany. Charcoal, particularly when derived from specific woods including Mahogany, has exceptional adsorptive qualities. This property enables it to efficiently attract and retain a wide range of pollutants, like chemical contaminants and some microbiological organisms, thereby facilitating their removal from the water. Subsequently, there exists an extra layer of fine sand measuring 12 cm in thickness, which acts to enhance the filtering mechanism and guarantee a thorough purification process.

Regarding dimensions, the system has a height of 43 cm, with a top measurement of 28 cm x 38 cm and a base dimension of 22 cm x 33 cm. The proportions and design of this configuration are suggestive of a compact and efficient arrangement, with the primary objective of optimizing filtration while minimizing spatial needs.

The effectiveness of the system is ultimately ascertained by its practical implementation. Contaminated water was exposed to the process of filtration, with the aim of evaluating the system's capacity to perform in realistic and unfavorable situations.

Fundamentally, this experimental arrangement embodies a comprehensive methodology for the process of water purification. The system employs a multi-barrier cleansing technique by integrating physical filtering materials such as gravel and sand with the adsorptive properties of charcoal obtained from Mahogany. The assessment of its performance in the difficult water mixture will not only ascertain its immediate feasibility but also provide the foundation for eventual expansion and use in broader settings.

The filtering system's ability to purify water sources, seen in Figure 3, depends primarily on the use of mahogany charcoal within its design. Charcoal derived from certain woods such as mahogany is well known for its power to adsorb contaminants, rendering it a plausible choice for this role. Nevertheless, like all experimental trials, conclusive validation of effectiveness requires empirical results.

Modification with Mahogany Charcoal

Table 1 presents a comprehensive profiling of water quality after filtration processing. Three crucial parameters were analyzed: Total Coliform, Fecal Coliform, and Heterotrophic Plate Count (HPC). These indicators serve as signs of microbial pollution, where high readings could pose risks to health.

Table 1. Water Quality Analysis of Contaminated Water Treated with Mahogany Charcoal Filtration System

Result of Analysis			
Total Coliform (MPN/100 mL)	**Fecal Coliform (MPN/100 mL)**	**HPC CFU/ 100 mL**	**Remarks**
>8	>8	<500	**FAILED**
Standard Requirement <1.1	<1.1	<500	

Undoubtedly, though the filter mechanism was thoughtfully engineered, it did not accomplish the intended purity standards based on the tabulated information. Both Total and Fecal Coliform counts far surpassed acceptable thresholds, measuring over 8 MPN/100 mL when fewer than 1.1 MPN/100 mL was the strict criterion. Moreover, the high particle count (HPC), another gauge of water quality, exceeded its limit by showing more than 500 colony-forming units per each 100 milliliters (CFU/100 mL).

Clearly, a serious issue emerges: the water retained health hazards despite treatment and was rendered unfit for drinking. The results emphasize the intricate nature and difficulties inherent in water purification, especially relying solely on a single filtering medium like mahogany charcoal.

Clearly, adjustments to the filtration system are urgently needed as revealed by these findings. While mahogany charcoal displayed some filtering capacity, coupling it with other purification methods or materials may optimize its efficacy. The empirical data in Table 4 plays a crucial role as feedback, informing and steering subsequent actions in developing an enhanced, comprehensive water purification solution. Repeated scientific testing, as shown here, views failures not as endings but as signposts guiding the next phase of investigation.

Modification with Coconut Shell Charcoal

The data in Table 2 presents a preliminary evaluation of the difficulties encountered when using an enhanced filter system with coconut shell charcoal to purify a combination of deep well water. Despite coconut charcoal's renowned adsorptive attributes, the approach failed to achieve satisfactory purification levels. This is evidenced by increased Total Coliform, Fecal Coliform, and HPC concentrations which surpassed safety limits.

Table 2. Water Quality Analysis of Contaminated Water Treated with Coconut Shell Charcoal Filtration System

Result of Analysis			
Total Coliform (MPN/100 mL)	**Fecal Coliform (MPN/100 mL)**	**HPC CFU/ 100 mL**	**Remarks**
>8	>8	>500	**FAILED**
Standard Requirement <1.1	<1.1	<500	

Performance was consistent across flow rates, remaining subpar. At one liter per minute, water quality stayed deficient, implying coconut shell charcoal filtering may be inadequate for removing contaminants in the mixed deep well water. This claim is reinforced by comparable findings at a decreased 200 mL per minute rate.

The repeated lack of success across various flow rates underscores the intricate nature of water pollution and prompts queries regarding exclusively relying on coconut shell charcoal purification. The results indicate while coconut shell charcoal can absorb some pollutants, its capacity may be insufficient for the wide range of impurities in mixed deep well water's complex constitution. The findings stress the need for a comprehensive or multi-step filtering plan capable of effectively addressing a broad spectrum of contaminants.

Integration of UV Sterilizer

Table 3. Efficacy of Coconut Shell Charcoal Filtration System Enhanced with UV Sterilization

Result of Analysis			
Total Coliform (MPN/100 mL)	**Fecal Coliform (MPN/100 mL)**	**HPC CFU/ 100 mL**	**Remarks**
<1.1	<1.1	<500	**PASSED**
Standard Requirement <1.1	<1.1	<500	

The incorporation of a UV Sterilizer into the filter system has shown a significant improvement in the quality of the treated water. As seen in Table 3, the effectiveness of the coconut shell charcoal filtration system is presented. The water has been subjected to UV Sterilization, resulting in an improvement in its quality that now complies with the necessary safety criteria for Total Coliform, Fecal Coliform, and HPC. The obtained findings have significance due to their adherence to the established safety criteria.

The effective technique in water purification has been attributed to the combined impact of the adsorptive qualities of coconut shell charcoal and the microbiological contaminant elimination capabilities of the UV sterilizer. The collaboration between different components guarantees that both particle and microbiological pollutants are efficiently dealt with.

Economic Viability of the Project

To evaluate the economic viability of the project, the researcher ascertained the quantity of 20-liter water containers that must be sold in order to offset the project's costs, thereby attaining a point of financial equilibrium. The task at hand pertains to the computation of the Equivalent Worth (EW) of the project's net cash flow, particularly with regards to the sales of the 20-liter water containers. The mathematical expression for this computation is provided in Equation 1 (Sullivan, G., et al., 2015).

$$EW = f(y)$$

where:

EW - an equivalent worth (Present Worth, Annual Worth, or Future Worth) calculation for the net cash flow

Y - factor of interest affecting the equivalent-worth values (in this case, the 20-liters water container)

To enhance the economic feasibility of the project, we will use the Conventional Benefit-Cost (B-C) Ratio via the application of the Present Worth approach, as cited in Sullivan G, et. al (2015). The mathematical expression is as follows:

$$B - C = \frac{\text{PW(benefits of the proposed project)}}{\text{PW(total costs of the proposed project)}}$$

$$B - C = \frac{\text{PW}(B)}{I - \text{PW(MV)} + \text{PW(O\&M)}}$$

where:

PW(·) - present worth of (·)

B - benefits of the proposed project

I - initial investment in the proposed project

MV - market value at the end of useful life

O&M - Operating and maintenance costs of the project.

If B-C ≥ 1 - Accept the project as economically justified the estimates.

If B-C ≤ 1 - the project is not economically acceptable

Results and Discussions

Design of the Water Treatment System

The water filter design was guided by several important criteria. A filter requiring an acceptable flow rate was needed, along with the ability to remove harmful impurities from water supplies. The design also aimed to create a small-scale and affordable solution. Figure 4 displays the schematic of the final water treatment concept.

The constructed filtration system utilized a large cylindrical drum measuring seventeen inches in diameter and thirty-two inches in height, holding around two hundred liters of capacity. The drum was filled with layers of charcoal, variously sized beds of sand, and gravel. This drum was chosen due to its widespread availability, simple removal of filter materials thanks to spacious internal dimensions, and low expenses associated with building this design. The arrangement of sand, known as the filter bed, strongly influences purification efficiency. River sediment was gathered, rinsed, and screened to obtain the sand. Gravel was also collected directly from the nearby riverbed. Locally sourced coconut shells were burned to create charcoal, then crushed and sifted through mesh screens retaining only pieces between half a millimeter to one and a half millimeters in size. Inlet and outlet pipes were placed at the top and bottom respectively to route water into and out of the drum's purification process. Its inner contents were organized with fine sand, fine charcoal, more fine sand, coarse sand topping gravel at the base. An automatic mechanism-controlled water levels during operation. Further downstream, a sterilizer utilizing twelve watts of power at one gallon per minute capacity was installed to disinfect water exiting the drum. A drain valve was also added. Modelling predicted a flow rate of around two hundred fifty milliliters per minute during continuous use.

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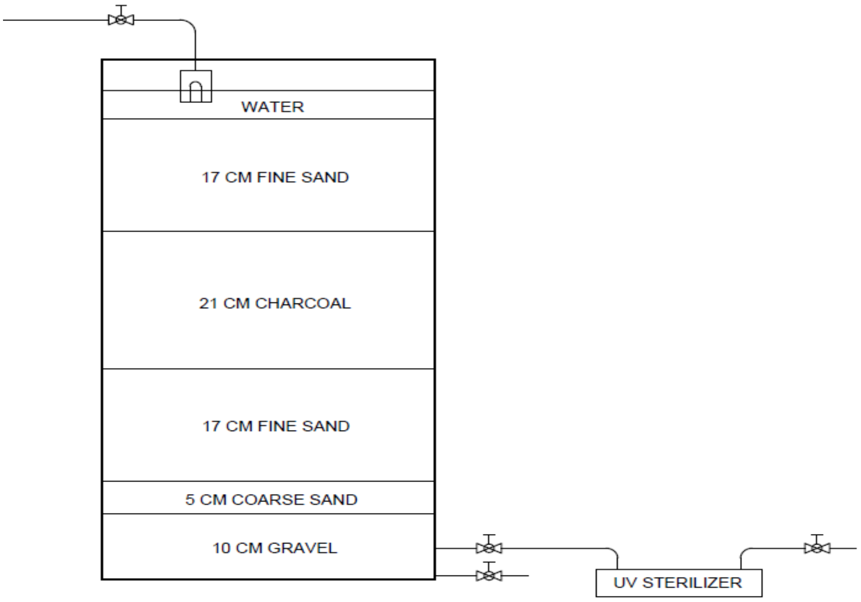


Figure 4. Schematic Diagram of the Final Design

Sizing the system relied upon daily consumption needs for the target community. It was tailored to serve roughly ten neighboring families averaging four point three four members each. Collectively, these eight households required approximately one hundred thirty-eight point eighty eight (138.88) liters of water daily strictly for drinking. With continuous use, the two hundred (200) liter capacity would take around thirteen hours and twenty minutes to fill

Physical and Bacteriological Test

Physical Test Result

Table 4 displays extensive data related to water quality parameters during diverse stages and flow rates of filtration and sterilization. This information serves as a fundamental basis for comprehending the impacts of these processes on pivotal water quality metrics like pH, color, conductivity, total dissolved solids (TDS), and turbidity.

Table 4. Water Quality Parameters at Different Stages and Flow Rates of Filtration and Sterilization

Standard	Ph (≤ 6.5 - 8.5)	Color (≤ 10 TCU)	Conductivity	TDS (≤500)	Turbidity (≤ 5 FTU)
Raw water	8.85	281	481	241	38
Filtered at 1000 mL/min	8.99	20	498	249	2
Filtered at 750 mL/min	8.11	15	497	249	1
Filtered at 500 mL/min	8.03	11	497	249	4
Filtered at 250 mL/min	8.03	9	500	250	3
Sterilized at 1000 mL/min	8.02	19	502	251	2
Sterilized at 750 mL/min	7.99	14	496	248	3
Sterilized at 500 mL/min	7.97	11	497	249	3
Sterilized at 250 mL/min	7.99	8	500	250	3

The guidelines asserted by WHO propose that pH values do not have a definitive health effect. However, they advise a pH scope between 6.5 and 8.5 as a general standard to shield water infrastructure and lessen the risks of corrosion and scaling. It merits noting that the pH levels of filtered water demonstrate fluctuations at assorted flow rates, with some exceeding the upper limit. This necessitates inspection of the buffering abilities of the filtering medium and potential need for pH modification processes.

The color parameter shows a significant decrease throughout the filtering process, especially at lower flow rates. This indicates the potency of the filtration system in removing color, which is crucial for maintaining aesthetic quality and acceptance among customers. Extensive studies by Aziz et al. emphasized the remarkable proficiency of activated carbon in this regard via adsorption.

Turbidity exhibits a comparable pattern, significantly decreasing after filtration and during sterilization. This is extremely important owing to EPA's maximum contaminant level of 1 NTU for filtered water to mitigate microbial contamination risk. Disease transmission prevention, specifically cholera and giardiasis, necessitates lowering turbidity as elucidated by Edberg et al.

The conductivity and TDS levels, which serve as indicators of ion presence, do not demonstrate substantial changes throughout filtration and sterilization processes at different flow rates. This observation aligns with research by Snoeyink and Jenkins, who elucidated standard filtering methods do not possess intrinsic efficacy in eliminating dissolved ions. Furthermore, TDS levels regularly stay below the WHO standard limit of 500 mg/L. As a result, the water maintains reasonable quality in terms of dissolved solids.

During diverse phases of sterilization, minor variations seen in the parameters may suggest sterilization has a minor effect on these specific water quality metrics. Therefore, more research is necessary to investigate potential consequences of sterilization on microbiological quality, which is not included in the supplied table.

Bacteriological Test Result

Table 5. Efficacy of Various Filtration and Sterilization Flow Rates in Meeting Bacteriological Water Quality Standards

Sample	HPU CFU/ml (<500)	Total Coliforms MPN/ml (<1.1)	Thermotolerant (Fecal) Coliforms MPN/ml (<1.1)	Remarks
Raw	>500	>8	>8	FAILED
Filtered at 1000 mL/min	>500	>8	>8	FAILED
Filtered at 750 mL/min	>500	>8	>8	FAILED
Filtered at 500ml/min	>500	>8	>8	FAILED
Filtered at 250 ml/min	<500	<1.1	<1.1	PASSED
Sterilized at 1000 mL/min	>500	>8	>8	FAILED
Sterilized at 750 mL/min	>500	>8	>8	FAILED
Sterilized at 500ml/min	>500	>8	>8	FAILED
Sterilized at 250 ml/min	<500	<1.1	<1.1	PASSED

Observations recorded in Table 5 are a critical look at the effect of varying flow rates on filtration and sterilization bacteriology columns in water systems. Such is demonstrated by the data in Table: Both the filtration and sterilization protocols are highly effective, even at a reduced flow rate of 250 mL/min. The requirement criterion is, once again, 500 CFU/mL for heterotrophic plate count (HPU) and 1.1 MPN/ml for total or thermotolerant coliforms. It is seen that in this complex relationship between flow rate and bacterial eliminations, different flow rates lead to different bacteriological results.

Microbial water quality and treatment context, the observed performance at a flow rate of 250 mL/min in removing bacteriological entities to permissible levels is consistent with what Tchobanoglous, Burton, and Stensel (2003) describe as a phenomenon where reducing flow rates or increasing hydraulic retention times enhances the efficacy of mechanical and biological treatment protocols. This flow rate performs according to that rule. This may result mainly from better solid-liquid separation –or better still in terms of appearance on our graph of scum area, from more pronounced sludge settling downwards due to a more rectangular up flow stream velocity enough to produce settling zones and then further settling– and the greater interaction (particle collisions) between disinfectants and microorganisms that results is further increasing microbial reduction.

At the same time, flow rates greater than 250 mL/min were unable to consistently reach the stipulated bacterial quality standards. This suggests that contact time or mechanical removal were insufficient. Higher flow rates cannot always ensure complete bacterial removal or inactivation. Limitations in ensuring public health security may also yet rest mainly on this, given the well-established relationship between coliform bacteria numbers and the presence of pathogenic organisms in water sources (Alajlan et al., 2022). This paves the way for diseases to be transmitted by drinking water, particularly through consumption of waters where fecal coliforms are present.

Observing the previously suggested performance of 250 mL/min would seem to be better suctioning for bacteriological control, but all the same, there is an urgent need to explore--also what effects there may be on system throughput, as well whether reduced flow rates are feasible in larger-scale treatment plants or if problems will arise in maintaining operations with these changes. To construct a water treatment paradigm that is both sustainable and health-protective, grasping the bacteriological generation data and these compound elements together is necessary.

The comparative analysis of Table 6, which contains water quality parameter data from a high diversity of water systems (distilled, purified drinking water, faucet water refilling stations, and biochar-biocon pressed systems), gives deep insight into how the safety and quality differ sources of the same can cold water.

Table 6. Comparative Analysis of Water Quality Parameters: Distilled, Purified, Refilling Station, and Biochar-Based System

Standard	Ph (≤ 6.5 - 8.5)	Color (≤ 10 TCU)	Conductivity	TDS (≤500)	Turbidity (≤ 5 FTU)
Distilled Drinking Water	8.65	0	26.3	13.15	0
Purified Drinking Water	7.69	0	7.37	3.69	0
Refilling station	6.12	0	28.3	14.15	0
Biochar-Based System	7.99	8	500	250	3

Even though distilled drinking water has a pH of 8.65, its quality is extraordinary if we examine other parameters such as the original raw water measured before treating it, conductivity, color or TDS. Even if turbidity is 1 (5), this suggests that it content contains very pure liquid indeed! Purified drinking water at 7.69 pH has good purity and excellent water quality by the standards of the Water Testing Manual.

However, water obtained from refilling stations has a pH of 6.12, resulting in misgivings and anxiety about its microbiological characteristics. Several refilling stations had high levels of gas-producing strains of E. coli and coliform counts, and some did not attain a satisfactory level of health hygiene for sanitation quality. This is demonstrated in a study by Veza Azteria and Ernalinda Lovyana (2023). This provides proof that the unseen dangers of water from these sources are real and emphasizes once more the need to exercise strict supervision and control.

Conversely, the biochar-based system has high levels of conductivity and TDS, as well as a colored appearance, which indicate that its mineral content is substantial although its pH of 7.99 is acceptable. There are substantial reasons why the biochar system cannot simply be transplanted into the domain of purification: this study demonstrates that its application in treating potable water requires extremely careful gradation.

Lastly, this analysis concludes by stressing that there are too many difficulties in protecting the safety and purity of drinking water from all different sources. Although both distilled and purified waters typically show higher quality, the specific problems posed by biochar-based systems and the unpredictable nature of replenishment station water guarantee that watering our people's health will be an ongoing and intensive job requiring innumerable tests. It is anathema to equate the safety and quality of water coming from today 's miscellaneous water supplies with source derivation alone

In the provision of potable water, public health and safety can only be maintained by ongoing surveillance, strict adherence to sanitation protocols, and informing the public that there is variability. among sources for water quality.

Economic Viability Computations

Initial investment

From Bill of materials, the initial investment is worth P8,790.00.

Monthly water consumption for 8 families.

The Institute of Medicine of the National Academies recommends 2.7 liters for adult women and 3.7 liters for males each day. According to the recommendations, foods can supply about 20% of daily hydration intake. This suggests that plain water accounts for 80% of overall water consumption.

Average water consumption per person = 0.8 x (2.7 + 3.7)/2 = 2.56 liters

For the 8 families having an average of 4.34 members per family, the average daily consumption is;

= (2.56 liters/person) x (4.34 person/family) x (8 family) = 88.88 liters/day

= 2,666.50 liters per month

Revenue

The current cost of water in Villaverde is governed by the price structure of the local water refilling stations, which charges Php 25.00 for each 20-liter water container, or P1.25 per liter.

Revenue = (2,666.50 liters/month) x (P1.25/liter) = P3,333.12/month

Operation and Maintenance Cost

Operation Cost

The cost of operation is determined by electrical energy consumption and monthly laboratory tests. The Nuvelco's annual average pricing is P15.00 per kWh while the laboratory test cost P550.00. Regardless of the absence of water entering the system, the sterilizer must be turned on. That way, when there is water entering and no water entering the system, there is no need to turn the sterilizer on and off specifically when the storage tank is full. Because of this, it will be maintained that the water output of the system is safe to drink.

The electrical energy is

= (12 W x 1 kW/1000 W) x (720 hours/month) x (P15.00/kWh)

= P129.60/month

Operation cost = electrical energy cost + laboratory cost

= (P129.60+ P550.00)/month = P679.60/month

Maintenance Cost

The quarterly replacement of the charcoal filter, along with labor and electrical energy usage, contribute to the maintenance cost. It requires two sacks of charcoal, each costing P250.00, for a total of P500.00. The labor cost is P900.00, while the electrical energy needed for crushing the charcoal with a portable blender is estimated to be P100.00. The total quarterly maintenance cost is P1,500.00.

Conversion of effective annual interest rate to nominal interest rate

$$ER = (1 + \frac{i}{n})^n - 1$$, (Fernando, J., 2023)

where:

ER – effective annual interest rate

i - nominal rate

n – number of times interest is compounded per stated time,12 for monthly.

Using 6% effective annual interest rate,

$$0.06 = (1 + \frac{i}{12})^{12} - 1, i = 0.058411$$

The nominal interest rate per year is 5.8411% and the interest rate compounded monthly is 5.8411%/12 = 0.48676%.

Conversion of maintenance cost from quarterly into monthly

Below is the cash flow diagram of the quarterly maintenance cost and the corresponding monthly maintenance cost.

1500

The following formulas will be used:

$$P = F(1+i)^{-n}$$

Finding P given F

$$P = A(\frac{1-(1+i)^{-n}}{i})$$

Finding P given A

where:

P = present worth of money

F = future worth of money

A = equivalent end-of-period values in a uniform series continuing for a specified number of periods

i = interest rate per interest period

n = number of compounding periods

Using present worth method and 0.48676% compounded monthly, the equation is

$$P_{\text{quarterly}} = P_{\text{monthly}}$$

$$1500(1 + 0.0048676)^{-3} = \frac{MC}{0.0048676}(1 - (1 + 0.0048676)^{-3})$$

MC = P497.57/month

The converted monthly maintenance cost is P497.57.

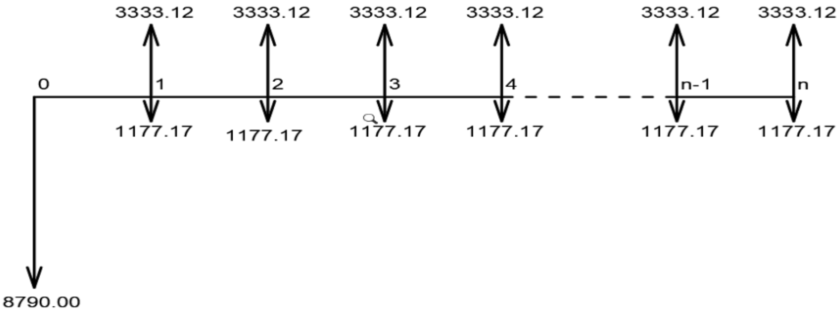
The total Operation and Maintenance cost is;

= (P679.60 + P497.57)/month

= P1,177.17/month

Calculation of the Breakeven Point

The determination of the breakeven point involves equating the present value (PW) of the project's monthly revenue (savings) to the PW of its combined investment and monthly O&M expenses, Sullivan, G., et al., (2015). Below is the cash flow diagram.



Using 0.48676% compounded monthly interest rate, the equation produces the following result:

$$PW\ (Investment\ +\ OM)\ =\ PW\ (Revenue)$$

$$8{,}790+\frac{1{,}177.17}{0.0048676}(1-(1+0.0048676)^{-n})$$

$$=\frac{3333.12}{0.0048676}(1-(1+0.0048676)^{-n})$$

$$n=4.13$$

The breakeven is equal to 4 months and 4 days, say 4 months.

Calculating the B-C Ratio

To enhance the economic feasibility of the project, the Conventional Benefit-Cost (B-C) Ratio by Present Worth method, as cited in Sullivan G, et. al (2015). The mathematical expression is as follows:

$$B-C=\frac{\text{PW(benefits of the proposed project)}}{\text{PW(total costs of the proposed project)}}$$

$$B-C=\frac{\text{PW}(B)}{I-\text{PW(SV)}+\text{PW(O\&M)}}$$

where:

PW(·)	-	present worth of (·)
B	-	benefits of the proposed project
I	-	initial investment in the proposed project
MV	-	salvage value at the end of useful life
O&M	-	Operating and maintenance costs of the project.
If B-C ≥ 1	-	Accept the project as economically justified the estimates.
If B-C ≤ 1	-	the project is not economically acceptable

The benefit of the project will come from the revenue itself. UV lamps have a lifespan of around 9,000 hours, according to freshwater-systems.com. The UV lamp is used 24 hours a day for roughly one (1) year. This signifies that the UV lamp has no salvage value after one year. The same is true for the system's other components. As a result, the system's usable life is one year, and its salvage value is zero. The computation of the B – C Ratio for one (1) year is shown below.

$$\boldsymbol{B-C}=\frac{\frac{3333.12}{0.0048676}(1-(1+0.0048676)^{-12})}{8{,}790-0+\frac{1{,}177.17}{0.0048676}(1-(1+0.0048676)^{-12})}$$

$$B-C=1.72>1$$

The B-C ratio is greater than one. Therefore, the project is economically acceptable.

Conclusions

After considering the goals of the project, it is possible to conclude that the system's design and construction may be considered accomplished. The 200-liter cylindrical container with a composite mixture of coconut shell charcoal, sand, and gravel was a great way to show how water treatment can be done using biochar in comparison. The introduction of UV sterilization also helped improve the overall system purification process, validating that water is treated thoroughly.

The technology's efficiency was tested under different conditions, and the received outcomes were striking. The post-treatment effect led to significant changes in the physical properties of water: pH indicator, color, conductivity, and turbidity. The system's ability to reduce microbiological pollutants to an appropriate rate for human use was supported by the results of bacteriological testing, especially at the flow rate of 250 mL/minute.

From an economical point of view, it provides a reasonable solution for the neighborhood. The breakeven analysis helps understand the point in which the original and ongoing costs of the project are returned to the community in terms of savings. According to the study, it happens in 4 years, and it means that the system will only start creating a cost-saving impact for the community over the three years of its usage. Another critical indicator, the Benefit-to-Cost ratio is 1.21, meaning that one unit of currency will return 1.21 units of currency, which makes the project economically sound. Thus, the Biochar-Based Water Treatment System can assure better access to clean water for the Villaverde community, proving to be economically feasible.

Acknowledgement

We extend our sincere gratitude to all individuals who contributed to the success of this study on the Biochar-Based Water Treatment System for Barangay Sawmill Villaverde, Nueva Vizcaya.

The assistance provided by the Barangay Sawmill community is acknowledged, as their cooperation and participation were essential for the completion of this study. Their readiness to share experiences and insights significantly enhanced our comprehension of local water quality issues.

We extend our sincere gratitude to Engr. Jonathan S. Rodolfo, co-researcher, for his dedication, collaboration, and technical expertise, which were instrumental in the design and development of the filtration system.

Finally, we acknowledge that the steadfast encouragement and support from our families and friends have consistently served as a significant source of motivation. This project was made possible by your confidence in our abilities.

We appreciate everyone's significant contributions to this endeavor.

References

Abhishek P. Kadam, Amruta A. Sawant, Shomit Varghese, & Sneha A. Turate (2018). Comparison of household grey water treatment using slow sand filter and slow sand aided with activated charcoal filter. International Journal of Innovative Science and Research Technology. Volume 4, Issue 3.

Ahmed, M. (2019). Design, construction and evaluation of charcoal, activated carbon, moringa seed and sand water filtration systems. Master's thesis.

Alajlan AA, Mukhtar LE, Almussallam AS, Alnuqaydan AM, Albakiri NS, Almutari TF, et al. (2022) Assessment of disinfectant efficacy in reducing microbial growth. PLoS ONE 17(6): e0269850. https://doi.org/10.1371/journal.pone.0269850

Azis, K., Mavriou, Z., Karpouzas, D. G., Ntougias, S., & Melidis, P. (2021). Evaluation of sand filtration and activated carbon adsorption for the post-treatment of a secondary biologically-treated fungicide-containing wastewater from fruit-packing industries. Processes, 9(7), 1223. MDPI AG. Retrieved from http://dx.doi.org/10.3390/pr9071223

Basu, P. (2013). Biomass Gassification, Pyrolysis, and Torrefaction (2nd Edition) p. 159. USA: Elsevier Inc.

Behring, S. (2021). Is charcoal carcinogenic? Retrieved from https://www.healthline.com/health/is-grilling-with-charcoal-or-other-heat-sources

Bolton, J., and Cotton, C. (2008). Ultraviolet disinfection. American Water Works Association: United States of Amerika.

Brandt, M., Johnson, M., Ratnayaka, F., Elphinston, A., & Ratnayaka, D., (2017). Twort'sWater Supply (7th Edition). United Kingdom: Elsevier Ltd.

Bridle, H. and Shultz, A. (2014). Waterborne Pathogens. Detection Methods and Applications. USA: Elsevier

Campbell, B. (2022). What is Water Distillation. Retrived from https://www.wwdmag.com/editorial-topical/what-is-articles/article/10940138/what-is-water-distillation. Retrieved 08/29/2022.

Campbell, B. (2022). What is Coagulation for Water Treatment. Retrived from https://www.wwdmag.com/editorial-topical/what-is-articles/article/10940184/what-is-coagulation-for-water-treatment.

Cecen, F. & Aktas, O. (2011). Activated Carbon for Water and Wastewater Treatment. Germany: Wiley-VCH Verlag & Co. KGaA

Danyuo Y., Arthur, E.K., Azeko, S.T., Obayemi, J.D., and Asuo, I.M. (2014). Design of locally produced activated carbon filter from agricultural waste for water purification. International Journal of Engineering Research & Technology (IJERT). Vol. 3 Issue 6

De Zuane, J. (1997). Handbook of Water Drinking Quality, Second Edition. John Wiley & Sons, Inc: Canada

Edberg, S. C., Rice, E. W., Karlin, R. J., & Allen, M. J. (2000). Escherichia coli: the best biological drinking water indicator for public health protection. Journal of Applied Microbiology Symposium Supplement, 88, 106S-116S.

EPA. (2023). Secondary Drinking Water Standards: Guidance for Nuisance Chemicals. U.S. Environmental Protection Agency. Retrieved from https://www.epa.gov/sdwa/secondary-drinking-water-standards-guidance-nuisance-chemicals

Fernando, J. (2023). Effective Annual Interest Rate: Definition, Formula, and Example.,Retrieved,,from,,investopedia.com/terms/e/effectiveinterest.asp

Formisano, B. (2022). How a Water Softener Works. Retrieved from https://www.thespruce.com/water-softeners-how-they-work-1824916. Retrieved 08/29/2022.

Global Health and Education Foundation (2007). Conventional Coagulation-Flocculation-Sedimentation. Safe Drinking Water is Essential. National Academy of Sciences.

Guan, P., Prasher, S., Afzal, M., George, S., Ronholm, J., Dhiman, J., & Patel, R. (2020). Removal of Escherichia coli from lake water in a biochar-amended biosand filtering system. Ecological Engineering, 150(2020), 105819. doi: 10.1016/j.ecoleng.2020.105819

Goncalves, L. & Pires, J. (2019). Bioenergy with carbon capture. Negative emission technologies (1st Ed., pp. 1-13). Available at https://doi.org/10.1016/B978-0-12-816229-3.00001-6

Helmenstine, A. M. (2019). Activated Charcoal and How it Works. Retrieved from https://www.thoughtco.com/how-does-activated-charcoal-work-604294

Holand, Theresa (2022). The Best Whole-house Water Filters for a Clean Water Supply. Retrieved from https://www.thespruce.com/best-home-water-filters-4159152. Retrieved 08/28/2022.

Ishaq, M., Afsheen, Z., and Khan, A. (2018). Disinfection Methods. http://dx.doi.org/10.5772/intechopen.80999

Kanaujia, Singh, B., & Singh, S. (2014). Novel Environmentally Benign Technique for the Removal of Fluoride, Arsenic and Coliform from Wastewater. International Journal of Sciences: Basic and Applied Research

Katal, R., Hasani, E., Farnam, M., Baei, M., & Ghayyem, M. (2012). Charcoal Ash as an Adsorbent for Ni (II) Adsorption and Its Application for Wastewater Treatment.

Journal of Chemical & Engineering Data, 57(2), 374–383. doi:10.1021/je200953h

Khiaria, Z., Alka, A., Kelloway, S., Mason, B., & Savidov, N. (2019). Integration of Biochar Filtration into Aquaponics: Effects on Particle Size Distribution and Turbidity Removal. doi: 10.1016/j.agwat.2019.105874

Kuo, Y.M., Lin, C.W., Huang, S.H., Chang, K.N., Chen, C.C. (2013). Effect of aerosol loading on breakthrough characteristics of activated charcoal cartridges. Journal of AerosolScience55, 57–65.

Mohan, D., Sarswat, A., Ok, Y.S., & Pittman, C. (2014). Organic and inorganic contaminants removal from water with biochar, a renewable, low cost and sustainable adsorbent – A critical review. Bioresource Technology, 160(2014),191–202. doi: 10.1016/j.biortech.2014.01.120

Mohanty, S., Cantrell, K., Nelson, K., & Boehm, A. (2014). Efficacy of biochar to Remove Escherichia coli from stormwater under steady and intermittent flow. Water Research, 61(2014), 288–296. doi: 10.1016/j.watres.2014.05.026

Mubarak, N., Fo, Y., Al-Salim, H., Sahu, J., Abdullah, E., Nizamuddin, S., Jayakumar, N., & Ganesan, P. (2015). Removal of Methylene Blue and Orange-G from Wastewater Using Magnetic Biochar. International Journal of Nanoscience, 14(4), 1550009. doi:10.1142/s0219581x1550009x

Myers, P. D. (2018). Activated Carbon Air Filters: Everything you need to know. Retrived from https://molekule.science/activated-carbon-air-filter/. Retrieved 6/24/2022.

Morris (2018). The Importance of Water. Retrieved from https://www.morriscardio.com/single-post/2018/05/30/The-Importance-of-Water.

Nguyen, X., Phuong, T., T.C., Hoan, V., Nguyen, P., Chang, W., Nguyen, D., Guo, W., Kumar, A., Duong Duc La, D., Bach, Q (2020). Combined biochar vertical flow and free-water surface constructed wetland system for dormitory sewage treatment and Reuse. Science of the Total Environment, https://doi.org/10.1016/j.scitotenv.2019.136404

Omotade, I., Alatise, M., & Olanrewaju, O. (2019). Recycling of aquaculture wastewater using charcoal based constructed wetlands. doi:10.1080/15226514.2018.1537247

Perry, C. & Gans, K. (June 2023). How Much Water You Should Drink A Day, According To Experts. Retrieved from forbes.com/health/body/how-much-water-you-should-drink-per-day/

Pokharel, A. (August 2020). Application of biochar for efficient municipal wastewater treatment. A master's thesis.

Reddy, K., Xie, T., & Dastgheibi, S. (2014). Evaluation of Biochar as a Potential Filter Media for the Removal of Mixed Contaminants from Urban Storm Water Runoff. Journal of Environmental Engineering, 140(12), 04014043. doi:10.1061/(asce)ee.1943-7870.0000872

Sawyer, C. N., McCarty, P. L., & Parkin, G. F. (2003). Chemistry for Environmental Engineering and Science. McGraw-Hill Education.

Shen, Y. (2020). A review on hydrothermal carbonization of biomass and plastic wastes to energy products. Biomass and Bioenergy, 134(2020), 105479. doi: 10.1016/j.biombioe.2020.105479

Snow, D. (2002). Plant Engineer's Reference Book. In George, S. (Ed). Water and Effluent (2nd Ed., pp. 9-10). Reed Educational and Professional Publishing Ltd

Sullivan, G., Wicks, E., and Koelling, P., (2015). Engineering Economy (16th Ed.). Pearson: USA

Tchobanoglous, G., Burton, F. L., & Stensel, H. D. (2003). Wastewater Engineering: Treatment and Reuse. McGraw-Hill.

USEPA. (2019). National Primary Drinking Water Regulations. U.S. Environmental Protection Agency. https://www.epa.gov/ground-water-and-drinking-water/national-primary-drinking-water-regulations

WHO. (2017). Guidelines for drinking-water quality: Fourth edition incorporating the first addendum. World Health Organization.

Woodward, J. (2022). What is a Reverse Osmosis System and How Does it Work? Retrieved from https://www.freshwater-systems.com/blogs/blog/what-is-reverse-osmosis

Woodward, J. (2021). What is Ozone Water Treatment? Retrieved from https://www.freshwatersystems.com/blogs/blog/what-is-ozone-water-treatment-and-how-does-it-work. Retrieved 08/29/2022.

Woodward, J. (2021). What is Reverse Osmosis and How Does it Work? Retrieved from https://www.freshwatersystems.com/blogs/blog/what-is-reverse-osmosis. Retrieved 12/31/2022.

Wulandari, L.K., Sudirman, I., & Munasih, V. (2020). The Design of Filtration System Using Coconut Shell Charcoal for Domestic Wastewater Purification. International Journal of Scientific Engineering and Science. Volume 4, Issue 11, pp. 19-23.

Zellner T., Prasa D., Färber E., Hoffmann-Walbeck P., Genser D., Eyer F. (2019). The use of activated charcoal to treat intoxications. Dtsch Arztebl Int; 116: 311–7. DOI: 10.3238/arztebl.2019.0311