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Understanding Customer Demand for Activated Biochar in The Egyptian Water Treatment Sector

Diana S. Raie,[1*] Hanan H. Shaat,[2] Enas Amdeha,[1]

[1] Egyptian Petroleum Research Institute, Cairo, Egypt
[2] Zewail City for Science and Technology, Giza, Egypt

[*]E-mail: raiediana@epri.sci.eg, raiediana@yahoo.com

Abstract. Egypt faces a critical water shortage, creating an urgent need for expanded water purification solutions. The government invests in water desalination projects to cover this water shortage, however, the dependence on imported water industry inputs increases the price of the purification of water treatment. Active biochar is a common chemical used in drinking water purification. Despite ongoing research on water treatment and recycling technologies, there is a lack of comprehensive market research and customer insights on activated biochar in Egypt. Herein, we present a customer discovery for the activated biochar market in the water treatment industry in Egypt. We interviewed 65 industry stakeholders, including water treatment experts, chemical suppliers, scientists, and key influencers. We found that the market of activated biochar in the water industry could be grouped into the following segments: household (domestic) filters, industrial and agricultural wastewater, desalination of seawater for drinking purposes, and water purification for industrial and farming requirements. In conclusion, activated biochar is an important chemical input for the water treatment industry in Egypt.

1. Introduction

Water scarcity is defined as the insufficient quantity or quality of water supply, measured by the ratio of human water demand to available water supply.[1], [2] Regions worldwide are experiencing severe water scarcity, adversely affecting human health, agriculture, and ecosystems. Access to clean and sufficient water has become a significant global challenge because of population growth, industrialisation, and climate change.[1], [2] So, providing clean water for our growing population has become a big challenge.

Lower-income countries are particularly vulnerable, where lack of infrastructure and limited resources exacerbate the problem.[1], [2] As an example of a low-income country, Egypt needs 80 billion cubic meters (bcm) of water per year.[3] The primary source of freshwater in the country is the River Nile, with a constant annual flow of 55.5 bcm.[4] In addition, Egypt has some nonconventional water resources, including desalinated seawater, rainwater harvesting, and desalinated groundwater.[3] So, Egypt has to have a strategic plan to find alternative water sources to address such a yearly water deficit.[3]

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The Egyptian government is expanding to build desalination plants to tackle water scarcity.[4] Thermal and membrane desalination techniques are used in Egypt to produce fresh water.[4] Thermal desalination technology depends on the distillation process and is applied to Ayoun Mosa, Abu Qir, and El Sokhna plants.[4] Water was desalinated by passing it through membranes, which remove salts and unwanted minerals.[4] At El-Galalah, El-Alameen, and East Port Said plants, membrane technology is used for water desalination.[4] Desalination is a promising solution to Egypt's water scarcity problem, as it can provide a reliable source of fresh water from seawater.[4] However, it is important to note that desalination can be expensive and energy-intensive, so it is important to carefully consider the costs and benefits before implementing large-scale desalination projects.

The capacity of the plant, the required energy, and the need for pretreatment control the selection of water treatment techniques.[4] Reverse osmosis (RO) membrane desalination plants consumed the lowest energy compared to other desalination processes.[4] In RO desalination plants, a primary treatment is conducted to remove pollutants that that deteriorate the membrane performance. Since, the suspended particles and chlorine are eradicated via sand and activated biochar (BC). Also, an anti-scale injection system is applied to eliminate calcium and sulfate salts. Such pretreatment filtration costs 15 % of the total cost of the RO desalination plant. In Egypt, except for sand filters, most of the inputs of RO plants are imported. In addition to the cost of technology, importing most of the water treatment process inputs is increasing the water purification cost.[4]

BC has adsorption capability due to its mesoporous structure and high surface area.[5], [6] The traditional sources for BC production were non-renewable precursors, such as coal and lignite, owing to their high carbon concentration, low mineral content and high porosity.[5] So, the non-renewability and finite reservation of the abovementioned sources have prompted the exploration of alternative sources for BC production, such as agricultural waste.

Importing BC (Harmonized System (HS) code: 38021) cost Egypt around 13 million US Dollars in 2021, according to the United Nations Commodity Trade (UN Comtrade) database.[7] The top trading partners of Egypt are India, USA, Germany, Sri Lanka, China, Turkey, Malaysia, Vietnam, France, and other countries.[7] So, Egypt has a significant demand for BC, which results in importing BC from a variety of countries.

Agricultural waste offers sustainable, cost-effective and eco-friendly replacements for traditional sources of BC.[6] Globally, 7-9 billion tons of municipal, agricultural, and industrial waste are produced yearly,[8] and Egypt produces 30 million tonnes of agricultural waste every year. Additionally, agricultural waste has a lower carbon footprint than traditional BC precursors.[9] Recycling a ton of waste into BC produces 6.6 kg of carbon dioxide equivalent emission, while landfilling organic waste produces 400 kg of carbon dioxide equivalent, [9], [10] and burning biomass, including agricultural waste, is responsible for 40% of carbon dioxide emissions and 8% of other emissions to the atmosphere.[11] So, the proposed value of recycling agricultural waste into BC is reducing greenhouse gas emissions,[9] supporting the circular economy and promoting sustainable waste management practices.[12]

Despite the national need for BC and the national maas production of biochar,[13] Egypt still imports all of its needs from BC. So, customer discovery for BC is an initial step for building a local product. Customer discovery involves understanding the problems, pain points, and desires of potential customers to ensure that BC matches the market needs. As data about the market of BC in the Egyptian market of the water industry is not fully covered, this research aims to fill this gap by understanding the BC market in Egypt's water treatment industry and its competitive alternatives.

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2. Methodology

W conducted interviews with 65 experts within water and wastewater treatment markets in Egypt to develop an understanding of customer needs. Based on the identified research gaps, this study is driven by the question of 'How can the Egyptian market for water and wastewater treatment adopt the national production of industrial inputs?'

3. Results and Discussion

We gathered information from 65 experts through interviews and analysed both qualitative and quantitative data to gain insights. We aim to provide sustainable and innovative solutions for purifying water and reducing waste.

Customer Segments

Figure 1a classifies the Egyptian market of water purification (based on the purpose of usage) and wastewater treatment (based on the source of wastewater). Irrigation with contaminated water can spread diseases to crops and livestock. Water purification can remove contaminants from irrigation water, which can help to protect crops and livestock from disease. Our interviewees (Figure 1a) highlight that cleaning water is applicable in farming for irrigation, animal feeding and drinking. So, Clean water is also important for farming activities.

Also, many industries need to purify the influent water before its usage. The purpose of treating industrial influents is usable for cooling towers, fire tanks, boilers, cleaning, and washing vegetables and fruits or as a solvent and production component. The filtration of water influents needs pretreatment by BC filters before passing through RO plants. Most RO plants use BC from a coconut source to pretreatment water, while some use anthracite and meta-bi-sulfite alternatives. BC is more expensive than meta-bi-sulfite but fits the RO system's long-term (two years) usability. The challenge in using BC is its recyclability.

On a quantitative level, the Egyptian market for water purification and wastewater treatment is divided into 3 main segments based on the sources of treated water, which are (1) wastewater (effluents), (2) agricultural and industrial (influent) water, and (3) drinking water, as shown in Figure 1b.

The treatment of agricultural wastewater is for re-use in irrigation. Using BC for industrial wastewater treatment depends on the motivation behind the treatment and the quality of wastewater. The motivation behind industrial wastewater treatment was fitting the environmental regulation of discharging wastewater (ISO 14000), reusing the treated effluents, and achieving zero discharge of hazardous chemicals in the future. Some industrial wastewater passes through BC water in case of reusing the treated wastewater in cooling towers and boilers, for example, while irrigating the surrounding landscape following rule 501/2015 does not need BC. Domestic (sewage) wastewater treatment does not need BC since the treated water is suitable for irrigation.

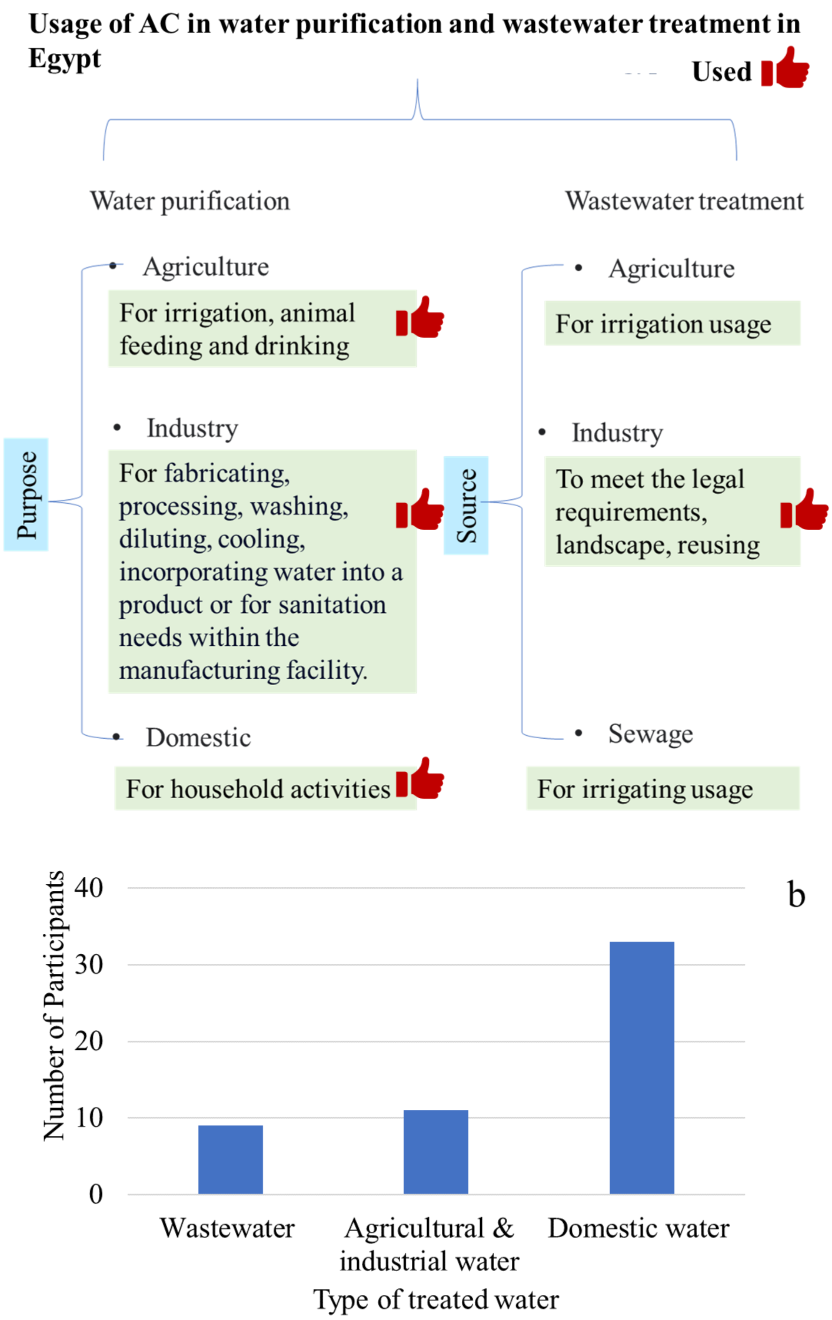

Figure 1. The usage BC in water and wastewater treatment industry in Egypt (a) Qualitative Analysis (b) Quantitative Analysis.

In Egypt, using BC in water purification for drinking purposes can be in desalination RO stations and domestic filters. Based on our interviews, RO plants are serviceable for desalinating sea water and groundwater in Egypt. The domestic filter purifies drinking water at the point of use. A variety of water treatment devices are available in the market for homeowners. Most of the available filters used BC. Some of the domestic filter suppliers import ready-to-be-used BC (BC housed in cartilages), which represented 33 % of our surveyed sample, and others locally fill the cartilages. So, we selected desalinated drinking water as a focused market because of its importance and the accessibility of interviewees.

For the drinking water, the interviewees cover three main customer archetypes: decision makers (Chief executive officer and purchasing manager), payers (Chief financial officer), and in most of cases, decision-makers and payers are the same person. The influencers and recommenders are scientists, influencers and ex-customers, while the end users are often paid technicians. Beneficiaries are communities living around RO stations, strategic managers and public relationship managers in NGO, and physicians and health working staff sectors. To sum up, interviewing customers validated that there are both market needs for replacing the imported BC with a nationally produced one made in Egypt.

Value Proposition

During our interviews with water and wastewater treatment companies for customer discovery of BC in Egypt, the value propositions of the national production of BC with an order of ranking of purifying water, cost saving, quality performance, and eco-friendly product were well acknowledged, as shown in Figure 2.

Chlorine is a widely used disinfectant in water treatment plants, but it can also negatively affect membranes. Chlorine can destroy membranes, contribute to deposits on the membrane surface, influence taste and odour and increase energy consumption.[14] By removing chlorine, the RO system can operate effectively, provide high-quality water, reduce maintenance requirements, and assure long-term performance and cost-effectiveness. The mechanism of removing chlorine from water using BC involves the process of adsorption. BC, with its high surface area and porous structure, attracts and traps chlorine molecules when water containing chlorine comes into contact with it. Through adsorption, the chlorine molecules bind to the surface of the BC particles, effectively removing them from the water.[15] This process prevents the chlorine from re-entering the water stream and damaging the RO membrane.

To assess the quality of BC, the iodine number is used as an important characteristic of BC that serves as a measure of its adsorption capacity. It quantifies the amount of iodine, in milligrams, that may be adsorbed by one gram of BC under certain conditions. The iodine number represents the microporous surface area and the presence of microscopic pores in the BC structure. A higher iodine value implies more adsorption capacity, which means the BC can successfully remove a bigger volume of pollutants, toxins, and odorous chemicals from water.[16]

During our interviews with wastewater companies and water treatment professionals in Egypt for the purpose of customer discovery regarding BC, we learned a lot about the perceived value propositions of Egyptian-made BC.

According to the order of rating based on feedback from all interviewees, the major value proposition was its ability to efficiently remove pollutants; chlorine, colour, suspended solids and odour; from water. This acknowledgement of its purification powers emphasises the need for clean and safe water in various industries, including municipal water treatment, industrial operations, and wastewater management. The interviewees praised BC's capacity to remove pollutants, contaminants, and odours from water, highlighting its importance in securing water quality.

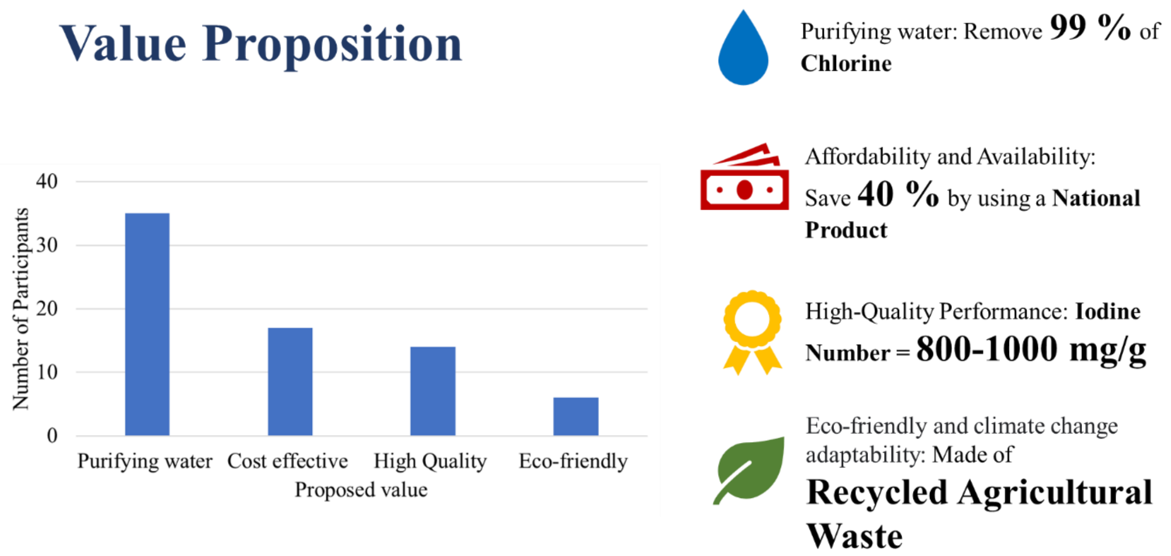

Figure 2. Proposed values for BC in water purification and wastewater treatment industry.

Additionally, 49 % of the interviewees emphasised the significant cost-saving potential of using Egyptian-made BC, demonstrating that it provides an affordable solution for water treatment demands. This cost-effectiveness can be due to the national production, which costs less than importing BC from abroad. Besides, the raw materials are agricultural wastes with very low cost. Moreover, BC's adsorption capabilities can easily remove contaminants and organic compounds from water, eliminating the need for further treatment stages or costly alternatives.

Furthermore, 40 % of the interviewees emphasised the value proposition of high efficiency and quality performance, demonstrating that the national production of BC is considered a reliable and high-performing choice. The interviewees emphasised BC's dependability and effectiveness in reaching targeted water treatment outcomes.

Around 17 % of the interviewees mentioned the value of an eco-friendly product, revealing an increasing awareness and appreciation for sustainable solutions in the water treatment sector. Because it is a natural and renewable material, BC is seen as an environmentally benign alternative to various chemical-based water treatment procedures such as anthracite and sodium meta-bi-sulfite. Its ability to eliminate impurities such as chlorine, colour, and odour without introducing harmful compounds corresponds with the growing emphasis on environmentally sensitive practices and regulations.

Some customers acknowledge the value propositions supplied by Egyptian-produced BC, particularly in terms of water purification, cost savings, quality performance, and eco-friendliness. As a result, its potential as a valuable solution for tackling water treatment difficulties and satisfying industry sustainability goals is highlighted. The main value of BC for customers was purifying water, and each customer selected an additional value of cost, quality or eco-friendliness. Both the importance of cost and quality for BC were on the same level of interest by customers.

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Channels
Our interview findings revealed that water and wastewater treatment companies in Egypt have three main distribution channels for BC, as shown in Figure 3:

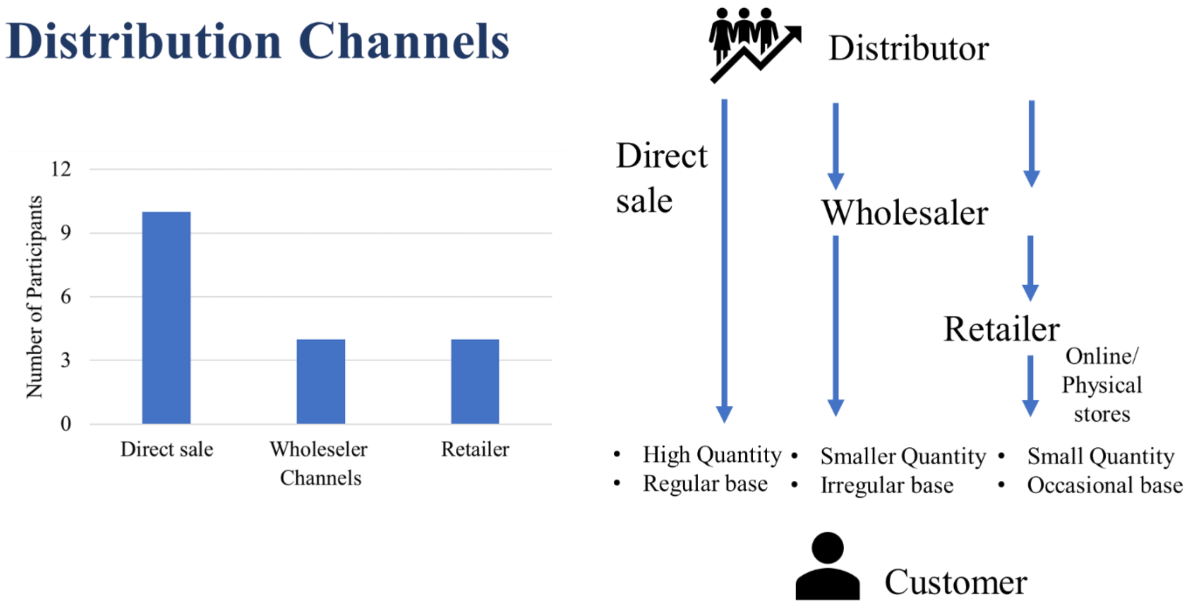

Figure 3. Channels of AC from Distributions to Customers.

1. Direct sales: Distributors sell BC directly to water treatment companies, either through stores or websites. This is the most common channel for large companies that need a large volume of BC regularly. Direct sales through physical stores and websites are generally recommended for businesses that need a reliable and steady supply of BC.

2. Indirect sales: Distributors sell BC to wholesalers, who then sell it to water treatment companies. This channel is more common for small and medium-sized companies that need a smaller volume of BC or that need it irregularly.

3. Retailers sales: Wholesalers sell BC to retailers, who then sell BC to water treatment companies online or via physical stores. This is a convenient option for companies that need to purchase small quantities of BC on an occasional basis. Only three of the ten companies we interviewed used online sales.

Overall, our findings suggest that the direct sales channel is the specific distribution channel that a water treatment company uses, depending on its needs and preferences. The dominant distribution channel for BC in Egypt. This is likely because large water treatment companies need a large volume of BC regularly. However, indirect and online sales are also important channels, especially for small and medium-sized companies and companies that need to purchase smaller quantities of BC occasionally.

Customer Relationships
Customer relationships are the strategies and tactics to get, keep and grow customers. In Egypt, the distributors of new technologies get their customers in the water treatment companies via free samples, workshops, conferences, courses and scientific discussions. Our study found that 16 interviewees

successfully used this method, resulting in requests for free samples to be tested. Customer service and product certification are keys for keeping the customers retained with the products. According to four interviewees in the study, customers can be kept and encouraged to use more BC by implementing a loyalty program that offers points, rewards, discounts, product updates, newsletters, and consulting services to address manufacturing issues. The sales grow via promotion, referral and sponsorship. Finally, referrals generate a viral loop by recommending BC to other customers and taking a special discount.

Competitors and Alternatives
From customer interviews, the key player of BC in Egypt is Jacobi, imported from Sweden. The alternatives are anthracite and sodium meta-bi-sulfite. In pharmaceutical industries, the Ministry of Health does not recommend BC as it is considered a suitable medium for organisms, so they prefer to use a chemical substance for treatment, such as sodium metabisulfite in RO stations for pharmaceutical industries. Using chelating and adsorbent materials like sodium metabisulfite and BC and selecting a specific one will depend on the client's budget; some of them prefer to increase capital cost with a long lifetime (BC is recommended), while others prefer decreased running cost with short lifetime (chemical method).

Growing environmental concerns have produced a widespread need for the development of sustainable waste management technologies and their transformation into value-added products, such as BC, for water treatment applications. Producing BC via thermochemical processing is a sustainable solution to biomass conversion and waste management.[17] Agricultural and industrial wastes are frequently promising option sources for cost-effective BC, given their abundant availability and zero price [18]. Furthermore, the use of waste as BC precursors is typically viewed as an alternate option for their environmental management and economic valorisation, which is consistent with circular economy principles and postpones their disposal as end-of-life leftovers.[19]

The social acceptance of BC derived from agricultural waste for water treatment is critical for manufacturing and the economy. Lower levels of societal approval would diminish customer desires and revenues. As a result, successful waste-to-value conversion needs to examine and enhance social acceptance and penetration. As a result, public awareness campaigns are required to educate consumers and distributors.[20]

Conclusion
Water shortage urgently requires expanding water purification in Egypt. Yet, Egypt imports all its water treatment inputs, which should be localised. We collected data by interviewing 65 customers in the Egyptian market of water and wastewater treatment. We concluded that the national production of BC has a market in Egypt in the water treatment industry. Affordable products are an essential step for avoiding the dollar gap. Some suppliers and customers know the importance of eco-friendly products and their impact on climate change. This study will open a gate for the national production of BC in Egypt.

Author Contribution
DSR: Conceptualisation and fundraising. All authors equally contributed to the data collection analysis and editing of the manuscript.

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