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Assessment of water footprint in the Jordanian industrial sector as a means for sustainable water resources management

Ocena śladu wodnego w sektorze przemysłowym w Jordanii jako wyznacznik do rozwoju zrównoważonego zarządzania zasobami wodnymi

Haneen H. Darwish, Samer Talozi

Jordan University of Science and Technology

ABSTRACT: This study examines the impact of industrial water consumption by calculating the Water Footprint (WF) of major industrial products produced in Jordan. The WF assessment considers the entire supply chain, which is divided into the blue and grey WF, using chain-summation and stepwise accumulative approaches. A total of 28 industrial subsectors were analyzed, and comprehensive data was collected from diverse statistical databases for the period 2011–2013. The information covered various aspects including water consumption quantities, wastewater generation amounts, industrial production quantities, and additional relevant data obtained from industry surveys, environment surveys, and economic statistics provided by the Department of Statistics of Jordan. The results indicate that the mining of chemical and fertilizer minerals subsector had the highest blue WF at 13,517 m^3/kg, while the highest grey WF was found for the refined petroleum products subsector at 1,193 m^3/kg. Conversely, the lowest blue WF was observed in the chemical products subsector, and the lowest grey WF in the rubber products subsector. The average internal blue and grey WFs for the year 2011 were 733 m^3/kg for blue water and 202 m^3/kg for grey water. In 2013, these averages were 915 m^3/kg for blue water and 108 m^3/kg for grey water. This study reveals notable trends in industrial water consumption, providing valuable insights for policymakers in Jordan, highlighting the need for sustainable water management practices and informing strategies to address water scarcity and pollution issues in the industrial sector.

Key words: virtual water, water footprint, industry, water resources, water management.

STRESZCZENIE: Celem niniejszego opracowania jest przeanalizowanie wpływu zużycia wody w przemyśle poprzez obliczenie śladu wodnego (WF) dla głównych produktów przemysłowych wytwarzanych w Jordanii. Ocena WF obejmuje cały łańcuch dostaw, który jest podzielony na niebieski i szary WF, przy użyciu metod sumowania łańcuchowego i stopniowej akumulacji. W ramach badań przeanalizowano łącznie 28 podsektorów przemysłowych, a kompleksowe dane zebrano z różnych baz statystycznych za okres 2011–2013. Informacje te obejmowały różne aspekty, w tym ilości zużywanej wody, ilości generowanych ścieków, ilości produkcji przemysłowej oraz dodatkowe istotne dane uzyskane z ankiet przemysłowych, ankiet środowiskowych i statystyk ekonomicznych dostarczonych przez Departament Statystyki Jordanii. Wyniki wskazują, że podsektor wydobycia minerałów chemicznych i nawozowych miał najwyższy niebieski WF wynoszący 13 517 m^3/kg, podczas gdy najwyższy szary WF, wynoszący 1193 m^3/kg, odnotowano w podsektorze rafinacji produktów naftowych. Najniższy niebieski WF wykazano dla podsektora produktów chemicznych, natomiast najniższy szary WF odnotowano w podsektorze produktów gumowych. Średni niebieski i szary WF w roku 2011 wynosił odpowiednio 733 m^3/kg dla wody niebieskiej i 202 m^3/kg dla wody szarej. Natomiast w 2013 roku te średnie wynosiły 915 m^3/kg dla wody niebieskiej i 108 m^3/kg dla wody szarej. Przeprowadzone badania ujawniają znaczące trendy w zużyciu wody przez przemysł, jak również dostarczają cennych informacji dla decydentów, podkreślając potrzebę zrównoważonych praktyk zarządzania wodą oraz wskazując strategie na rozwiązanie problemów związanych z niedoborem wody i zanieczyszczeniem w sektorze przemysłowym.

Słowa kluczowe: wirtualna woda, ślad wodny (WF), przemysł, zasoby wodne, zarządzanie zasobami wodą.

Corresponding author: H.H. Darwish, e-mail: *hhdarwish15@eng.just.edu.jo*

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Introduction

Water demand in Jordan is steadily increasing due to factors such as high population growth rates, urbanization, climate change, the influx of refugees, and economic development needs. The country's limited water resources are proving insufficient to meet the growing water demands (Ministry of Water and Irrigation, 2014, 2016). Water demand refers to the total amount of water required to meet the needs of the population, industries, and agriculture within the country. Furthermore, water scarcity in Jordan refers to the situation where freshwater availability is inadequate compared to the demand, resulting in an inability to meet the needs of the growing population and various sectors. Projections indicate a significant rise in total water demand in the coming years, expected to reach 1,609 million cubic meters (MCM) by 2025, and increase further to 2,013 MCM by 2040 (Ministry of Water and Irrigation, 2023). Moreover, Jordan's freshwater availability per capita per year stands at only 61 cubic meters, well below the globally recognized absolute water scarcity threshold of 500 cubic meters per capita annually (Ministry of Water and Irrigation, 2023). These figures underscore the critical need for effective water management strategies to ensure a sustainable and adequate water supply for the country's future. The challenging balance between water demand and scarcity in Jordan has driven the per capita water shares to alarming lows, which has provoked growing interest in advancing alternative and innovative options for water resources (Ministry of Water and Irrigation, 2014). Today and looking ahead, Jordan requires a sophisticated and integrated approach to water resources planning and management to safeguard the wellbeing of future generations.

Water is a cornerstone to the political, social, and economic wellbeing of Jordan. It impacts Jordan's security, trade, agriculture, finance, energy, and national prospects (Ministry of Water and Irrigation, 2016). Jordan's water resources are allocated across four main uses, ranked from highest use-levels to lowest use-levels: irrigation, municipal, industrial, and livestock. In 2020, total water use reached nearly 1128 MCM, distributed as follows: 51% for Agriculture and Nomadic uses, 46% for Domestic and Tourism, and 3% for industry (Ministry of Water and Irrigation, 2020). All of the sectors mentioned above rely on the accessibility of water for their growth and development. Increase in water shortages will affect these sectors, leading to future adverse impacts (Ministry of Water and Irrigation, 2015). As for the industrial sector, manufacturing is not limited by manpower, but depends on access to finance, reliable energy, and water. Without these resources, their growth will be constrained (Jordan Economic Growth Plan, 2018).

The Water Footprint (WF) tool offers an effective approach to address water scarcity through water accounting (Hoekstra et al., 2011). A WF analysis of the industrial sector is vital at this stage of development in Jordan. It will enhance understanding of freshwater usage and/or pollution across all industrial subsectors.

The WF analysis is used worldwide in order to better understand how water resources are used and for what purposes. The WF of a product is defined as a tool for measuring the direct (operations) and indirect (supply chain) freshwater consumption, as well as the amount of polluted water generated throughout the product's production chain (Hoekstra et al., 2011). It reveals levels of water consumption and pollution during its use for various purposes. The WF tool can be applied to different contexts, including processes, products, consumers, geographic areas, businesses, and/or humanity as a whole. It has proven beneficial in improving water strategies and management as a volumetric indicator that increases knowledge of freshwater withdrawal and water pollution (Hoekstra et al., 2011). Consequently, it raises awareness and contributes to solutions for mitigating the depletion of freshwater resources. This study aims to explore the WF of Jordan's industrial subsectors.

This research was carried out in Jordan, situated in the Middle East, bordered by Saudi Arabia to the south and southeast, Iraq to the northeast, and Syria to the north. Furthermore, Table 1 provides additional details about the country.

Based on Figure 1, it is evident that the eastern and southern regions of Jordan experience high rates of evaporation. Therefore, this research aims to explore how understanding industrial water consumption in Jordan can contribute to the sustainable management of water resources.

Table 1. Geographical and environmental characteristics of Jordan
Tabela 1. Charakterystyka geograficzna i środowiskowa Jordanii

Specification	Corresponding Value
Latitude	Between 29.2° and 33.4°
Longitude	Between 34.9° and 39.3°
Area	89,342 km^2
Climate	Hot summers and mild winters.
Landscapes	Diverse landscape including the Jordan Rift Valley, the Dead Sea, the Jordan River, and portions of the Arabian Desert

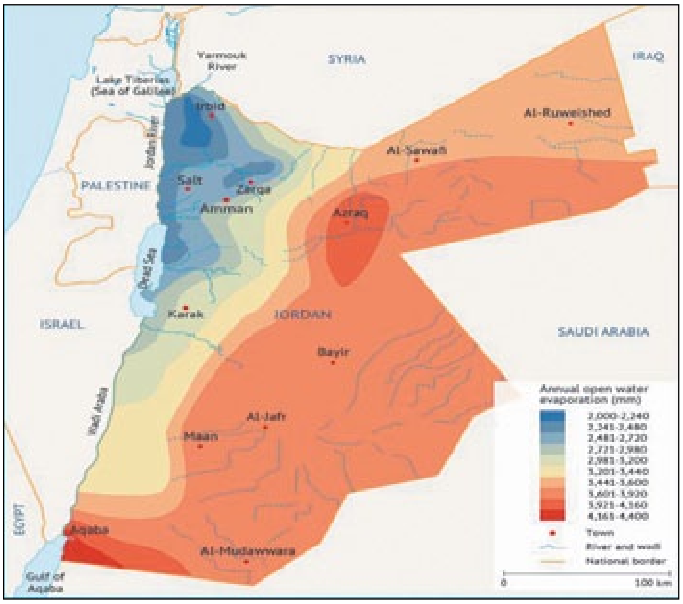

Figure 1. Annual rate of water evaporation in Jordan (Fanack Water, 2022)

Rysunek 1. Roczny wskaźnik parowania wody w Jordanii (Fanack Water, 2022)

Jordanian industry

The Jordanian industrial sector is primarily composed of three sub-sectors: manufacturing, extraction, and electricity and water. Manufacturing accounts for 15.2% of the GDP, while extraction for 2.2% of the GDP (Jordan Chamber of Industry, 2017). Extraction involves raw materials extraction from the earth's interior and encompasses mining industries, such as: phosphate, potash, natural gas, and petroleum products. Electricity and water accounts for 2.7% of the GDP (Jordan Chamber of Industry, 2017). This includes both electricity and water utilities.

Water is used at some stage of the production process of every manufactured product. The total amount of water involved in production is referred to as industrial water. Industrial water usage serves various purposes including processing, dilution, fabrication, washing, cooling, heating, incorporating water into a product, and cleaning the manufacturing plant. Each industrial subsector features distinct production processes and volumes that differ from one subsector to another. This leads to variations in water consumption levels and difficulties in efficient water resources management.

The expansion of Jordan's industrial sector is evidenced by the increasing number of industrial firms and establishments. In 1985, there were approximately 4,546 industrial facilities employing 43,313 workers. Two decades later, these numbers grew to 13,357 industrial facilities with about 150,000 predominantly Jordanian employees (DoS, 2006). Projections from the Ministry of Water and Irrigation & German Technical Cooperation (MWI & GTZ, 2004) indicate that industrial water demand is expected to reach 170 MCM by 2040, driven by high per capita demand and population growth. This escalating demand leading to water shortages poses significant threats to the Jordanian economy as a whole, potentially leading to unemployment, income declines, increased poverty, foreign exchange imbalances, and economic recession (Water Authority of Jordan, 2010).

Given the industrial sector's rapid production volume and net profits growth, the water demand is projected to increase by up to 300% by 2024, necessitating urgent attention (Ministry of Water and Irrigation, 2014). This study explores water consumption across various industries in Jordan in order to understand sector-specific variations.

The objective of this study is to guide water management in Jordan towards a new strategy to mitigate water scarcity by enhancing the sustainability of water resources use and management in the industrial sector. More specifically, this study aims to:

- Calculate the WF of major industrial products produced in Jordan along the entire supply chain (internal WF), considering the raw materials used in the production process;
- Aid as a resource in the management of water resources in order to achieve water sustainability within the industrial sector;
- Investigate the water situation in Jordan, given its water scarcity and high evaporation rates as illustrated in Figure 1.

Several data-related tools and approaches were employed in this study. Such evaluations aim to achieve a balance between ongoing industrial development and water security in Jordan. For example, industries with a low WF should receive greater encouragement and support compared to those with high WF, as a higher WF exacerbates industrial water demand in Jordan. Elevated WF values for products and processes contribute to unsustainable consumption patterns of local water resources. WF assessments can also empower decision-makers to propose new effective strategies and policies, leading to proper management of industrial water use. Consequently, this research contributes to enhancing the overall management of water resource in Jordan.

The WF tool as an assessment of industrial water consumption

The WF – terms and classification

The WF tool distinguishes between domestic and international water consumption, which is crucial for the sustainable development of the industrial sector in Jordan. The internal WF measures water use of water from the domestic and local resources in the production processes, while the external WF measures water use internationally for products destined for import or export (Hoekstra and Chapagain, 2007). The use of WF can facilitate water concentration by prioritizing the import of water-intensive products over local production, and export of products with lower water footprints. Importing water in its virtual helps alleviate pressure on limited water resources, enhances water security, and contributes to meeting Jordan's water demand.

Furthermore, the WF (internal and external) can be classified into three categories: blue, green, and grey water. The scope of this study is limited to the blue and grey WF. The blue WF is defined as "the utilization of freshwater resources, such as ground and surface water", the green WF is defined as "Utilization of green water resources, such as water that has been obtained from rain kept in the soil" whereas the grey WF is defined as "polluted water as a result of the production processes of products" (Hoekstra et al., 2011). The blue WF represents the amount of water that is evaporated, incorporated into products, or otherwise removed from the water cycle and cannot be readily reused, while the grey WF focuses on the amount of freshwater required to dilute the generated pollutants. Nevertheless, this tool can be used to analyze how industrial products manufacturing impacts water scarcity and pollution issues, thereby promoting the initiation of sustainable management of freshwater resources.

Global scale

To gain a deeper insight into WF assessment in Jordan, a review of global applications of the WF tool was conducted. Comparison of global and national scales enables mor accurate analysis of Jordan's industrial WF.

Chapagain and Hoekstra (2011) quantified the WF for rice production on a global scale, assessing the 13 largest rice-producing countries. Their study revealed that the total global WF for rice was 0.78 MCM/year, comprising 48% green, 44% blue, and 8% grey water. Virtual Water (VW) flows related to international rice trade was 0.031 MCM/year (Chapagain and Hoekstra, 2011). The study highlighted variations in the environmental impacts of rice production across different countries regarding factors such as water pollution and water scarcity. The environmental costs associated with water use in rice production are not factored into the price of rice. These costs can vary significantly depending on factors such as whether the rice is produced using dry or wet methods, as well as its source (Chapagain and Hoekstra, 2011).

Another study assessed the global WF of cotton products across the 15 largest cotton-producing countries. The global WF of cotton consumption was found to be over $2.5 \cdot 10^5$ MCM/year, with 42% blue water and 19% grey water (Chapagain et. al., 2006). Importantly, the study also shows that the average external blue WF for the consumption of cotton products in Jordan from 1997 to 2001 was estimated to be 48 MCM/year, and 13 MCM/year for the external grey WF for the same period. The average internal blue WF was estimated at 1 MCM/year, while the total internal WF was 3 MCM/year (Chapagain et. al., 2006). The results show that the lack of adequate water pricing mechanisms negatively impacts cotton consumers' accountability for the damage on remote water systems.

National scale

A study by Chouchane et al. (2015) documented the WF related to crop production sector in Tunisia, examining both irrigated and rain-fed agriculture at national and subnational levels. They found that during the period when crop production represented the largest share (87%) of the national production's WF, severe overall water shortages were recorded.

Schyns and Hoekstra (2014) demonstrated the added value of the human WF on the river basin level of Morocco, as well as a comprehensive assessment of the VW flows leaving and entering the country. This study also found that the WF assessment has an impact on national water policy. It takes into consideration the freshwater end-users and purposes, which are essential in determining the efficient and fair distribution of water. Additionally, the consideration of green and grey WF offers new perspectives on blue water scarcity, since pressure on blue water resources could be reduced by more efficient use of green water and reduced pollution.

Another study related to national-scale WF was performed by Wang et al. (2016), who measured China's WF for various subsectors of agriculture, such as hunting, forestry, and fishing, as well as for industrial sectors including mining and quarrying, food products, beverages, tobacco, non-metallic minerals, and textiles. This study used an input-output analysis and demonstrated how the WF was influenced by different policy developments. The authors concluded that macro-control policies should be planned in alignment with local governance policies to promote water conservation. Using WF calculations on a national scale can be beneficial for decision-making processes regarding water conservation policies, as it provides an overall perspective of the national available water resources.

Collection of data and methodology

Overview of Data Sources

Detailed datasets for the period 2011–2013 were utilized to perform the analysis and calculation of the WF of the industrial sector in Jordan. The first dataset for industrial water uses in Jordan comes from the Department of Statistics' (DoS), mainly from industry and environment surveys, economic statistics, and the economic establishments census. Freshwater consumption volumes were sourced from various origins, such as well water, public networks, water tankers, distilled water, and other sources, as provided in the "Environment Statistics" reports of DoS (2014, 2015a, 2016). Electricity consumption data was also obtained from the "Environment Statistics" reports of DoS (2014, 2015a, 2016). Moreover, quantitative industrial production data on a weight basis was obtained from the economy survey-price indices (Monthly quantitative Industrial Production Index), as shown in Table 3 in the Supplementary Information (SI) (Department of Statistics' Website a). All details related to the industrial external trade and industrial exports were provided from the economy survey-external trade that are illustrated in Table 4 in the SI (Department of Statistics' Website b).

The second dataset provides information about water withdrawals and pollution outputs for 28 economic activities (referring to the industrial subsectors in all DoS reports) and reported using codes according to the International Standard Industrial Classification (ISIC). ISIC is defined as a standard classification according to the type of economic activities (including goods and services) arranged, where enterprises can be rated based on the activity that they carry out (United Nations, 2008). Table 7 in the SI describes the ISIC codes for all of the major industrial subsectors included in this study.

The scope of this study is limited to Jordan's industrial sector, which can be divided into two main categories: (1) the water-intensive industries, which include the nine largest companies consuming about 86% of total water usage by industry in the year 2001, as shown in Table 5 in the SI; and (2) the non-water-intensive industries, including all of the remaining industries within the sector (MWI & GTZ, 2004).

Sample Description of Industrial Subsectors

A summary of descriptive statistics for the variables analyzed in the study is presented in Table 2. This table provides the arithmetic mean and standard deviation values for industrial production and water consumption during the three-year study period. The variables are abbreviated into one letter for simplification purposes. The average value of industrial output production, approximately 370 million JD, is derived from the data collected and analyzed from the industrial subsectors included in the study for the period 2011–2013. It indicates that the industrial plants in the sample are predominantly medium-sized. Further, the average value of industrial water quantities used in industrial processes is around 1,071 thousand m^3, obtained by calculating the average water usage for the same period, serving as an estimation of the average water consumption within the studied subsectors' industrial processes. For additional details, Table 3 in the SI presents the industrial production and water consumption data for each specific industrial subsector. The values presented in Table 2 were calculated based on the data provided in Table 3 in the SI.

Table 2. Descriptive statistics of variables used in the empirical analysis

Tabela 2. Statystyki opisowe zmiennych wykorzystanych w analizie empirycznej

Variables	Definitions	Mean	Standard Deviation
Q	Total value of industrial output production (Unit: thousand JD)	369 664	749 329
W	Total consumption quantity of industrial water (Unit: thousand m^3)	1071	3404

Calculation of the industrial WF

Calculation of a product WF

The product WF can be determined using one of two different approaches: the Chain-Summation Approach or the Stepwise Accumulative Approach. In this study, the Virtual WF (VWF) calculation requires knowledge and accounting of water used in domestic consumption (i.e. staff) and internal electricity power consumption.

The availability of the data determines which method can be applied to calculate the WF of the products. In this study, the first method, the Chain-Summation Approach, is used more broadly than the Stepwise Accumulative Approach. This is due to the availability of water consumption quantities and production volumes (parameters of Eq. (1)), which makes the first method more easily applied. Both the weight and price of the output products as well as the weight and WF of the input products (parameters of Eqs. (3)–(5)) are rarely counted for by the industrial subsectors. Thus, the second method is barely applied using the official data from the DoS.

The Chain-Summation Approach

This approach can be used for the manufacturing of one single industrial product. The WF of this sole output can be obtained by combining the WF of the inputs and the WF of the process, then dividing by the production quantity of the product [p], as shown in the following equation (Hoekstra et al., 2011):

$$WF_{prod} = \frac{\sum WF_{proc}[s]}{P[p]} \tag{1}$$

where:

WF_{prod} [p] – WF of output product p [volume/mass],

WF_{proc} [s] – process WF of process step s [volume/time],

P [p] – production quantity of product p [mass/time].

The blue WF in a process step (WF_{proc}, blue) is calculated as the sum of blue water evaporation, blue water incorporation into product and the lost return flow [volume/time] as shown in the following formula (Hoekstra et al., 2011):

$$\text{Blue } WF_{proc} = \text{Blue water evaporation} + \text{Blue water incorporation} + \text{Lost return flow} \quad (2)$$

The lost return flow refers to the part of the flow that does not return for reuse within the same place and period of withdrawal. In this study, the total internal blue WF consists of 3 parts: the product WF (direct WF), the energy WF and the employee WF (indirect WF).

The Stepwise Accumulative Approach

This is a general approach for calculating the product WF for several output products. In this case, the WF of the input needs to be distributed among the separate output products without double counting (Hoekstra et al., 2011):

$$WF_{product} = \left(WF_{proc}[p] + \sum_{i=1}^{n} \frac{WF_{prod}[i]}{Product\ fraction\ p,i} \right) \cdot Value\ fraction \quad (3)$$

where

WF_{prod} [i] –WF of input product i,

WF_{proc} [p] – process water footprint of the processing step that transforms the n input products into the z output products (where z is the number of output products that originate from the input products), expressed in water use per unit of processed product p (volume/mass).

The *product fraction* f_p [p, i] is defined as the ratio of quantities of both the obtained output product and the input product (mass/mass) (Hoekstra et al., 2011). In this equation, $w[p]$ represents the quantity of the output product (mass) obtained, and $w[i]$ represents the quantity of the input product. The equation is given by:

$$fp[p,i] = \frac{w[p]}{w[i]} \quad (4)$$

The *value fraction* f_v [p] is defined as the market value of an output product divided by the whole market value of all output products attained from input products (Hoekstra et al., 2011):

$$fv[p] = \frac{price[p] \cdot w[p]}{\sum_{p=1}^{z} \left(price[p] \cdot w[p] \right)} \quad (5)$$

Where *price* (p) is the price of an output product and $w[p]$ as defined above. Total virtual water flows are determined by multiplying, per subsector, the trade volume (in kg) with the total WF per unit of production of the exported product (i.e., internal WF in m^3/kg) (Mekonnen et al., 2015).

The total internal blue WF comprises the direct WF and the virtual (indirect) WF, as explained by Gu et al. (2015). The direct WF represents the water utilized in the production process and can be derived from Eq. (1) and Eq. (3). On the other hand, the virtual WF encompasses the water consumed during electricity power generation and for domestic purposes (e.g., staff). In accordance with Gu et al. (2015), the following equation was obtained to compute the total internal blue WF:

$$\text{Total internal blue WF} = \text{Direct WF} + \text{Virtual WF} \quad (6)$$
$$\text{Virtual WF} = \text{energy WF} + \text{employee WF}$$

The primary method used in calculating the WF combines the consumptive water use of blue and grey water with statistics on production, trade, and prices of products (assuming that green water is not included in industrial production). This method was introduced by Hoekstra et al. (2011). Estimating the WF of an industrial product involves the following steps: (1) identifying and schematizing the production system into linked process steps, (2) tracing the origin of the product's inputs in order to determine if the raw materials were imported from other countries or purchased locally, (3) obtaining data from the manufacturers and factories (the sources), as well as the required information related to the process steps that were taken into account through the full production chain of a certain product, and (4) estimating the volumes of consumed and polluted water over the entire process in the production chain to determine the blue and grey WF. The green WF quantifies the amount of rainwater used throughout the production process and evapotranspiration from fields, as well as the water incorporated into the yield (Hoekstra et al., 2011). This type of WF is related to agricultural products that are crop dependent. For industrial products, production starts with processing imported input materials as the first stage. Therefore, there are no agricultural production and crop harvesting stages, thus, there is no green WF for industrial products (Hoekstra and Chapagain, 2011).

Total WF Results

Total internal blue and grey WF for the industrial sector

The internal industrial WF within Jordan was calculated using Eq. (1) with available local data (Table 3 in the SI). The total blue and grey WF were calculated using the Chain-Summation method for each year of the study period, from 2011 to 2013, for the entire industrial sector including all subsectors. The results are shown in Figure 2.

The results demonstrate that the blue WF increased from 2011 to 2013 and, given the current circumstances, is expected to continue rising, adding more stress to the water resources in Jordan. Specifically, the blue WF of Jordan's industrial sector increased significantly from 773 m^3/kg in 2011 to 915 m^3/kg in 2013. Conversely, the grey WF appears to have decreased with time, as shown in Figure 2. This decline may indicate ongoing

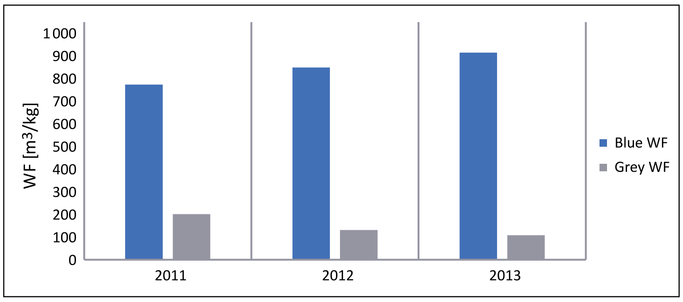

Figure 2. The average internal blue and grey WF of Jordan's industrial sector

Rysunek 2. Średni wewnętrzny niebieski i szary WF sektora przemysłowego Jordanii

efforts by the authorities to reduce water contamination. The grey WF was more than 200 m^3/kg in 2011 and decreased in 2012 and 2013, reaching about 100 m^3/kg in 2013.

To reiterate, it is important to note that the results reported in this section represent only the internal component of the WF. Estimating the external WF requires knowledge of the quantities and origins of raw materials, which is beyond the scope of this study. Figure 3 is the average total WF (blue and grey) in m^3/kg. As shown, there is a significant increase in the total blue and grey WF from 2011 to 2013.

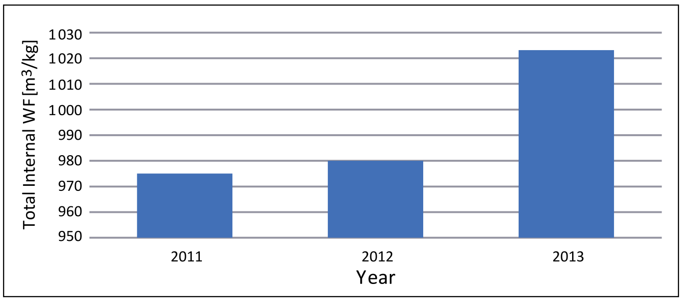

Figure 3. The average total internal WF [m^3/kg] for 3 years

Rysunek 3. Średni całkowity wewnętrzny WF (m^3/kg) z trzech analizowanych lat

The total internal blue WF of industrial subsectors

Figure 4 demonstrates the highest blue WF of the subsectors (Table 3, SI). The WF was calculated based on public datasets using Eq. (1). The mining of chemical and fertilizer minerals subsector has the highest internal blue WF, with about 13 517 m^3 of freshwater per kg of produced product. The next four highest industrial subsectors have an internal blue WF ranging from 1517 m^3/kg to 745 m^3/kg, as shown in Figure 4 below. On the other hand, the five lowest blue WF of the industrial subsectors are shown in Figure 5. The textiles and rubber subsectors have low blue WF estimated of about 16 m^3/kg and 17 m^3/kg of product, respectively. The tobacco products subsector's blue WF is 11 m^3 of water per kg of product, and the chemical products subsector has the lowest blue WF of the industrial sector, with about 10 m^3 of water per kg of product. Xu et al. (2017) indicated that the textile subsector demonstrated a relatively low blue WF value.

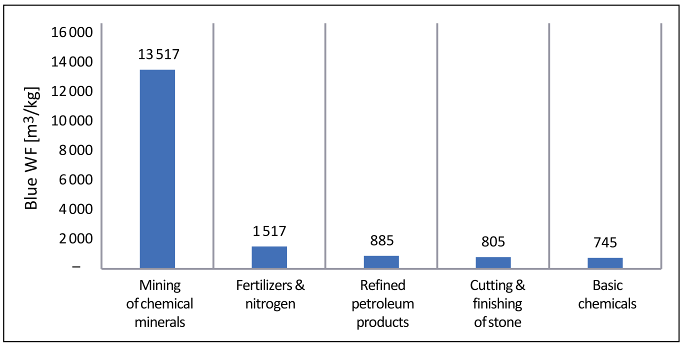

Figure 4. The 5 highest internal blue WF of the industrial subsectors

Rysunek 4. Pięć najwyższych wewnętrznych niebieskich WF w podsektorach przemysłowych

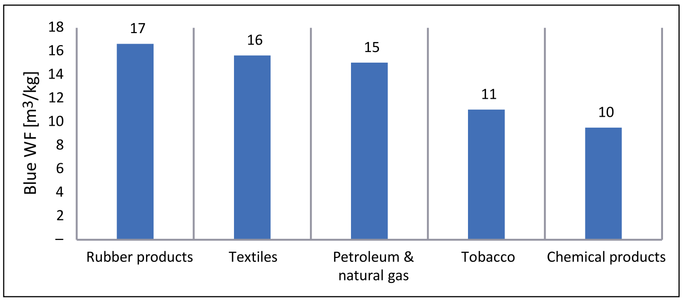

Figure 5. The 5 lowest internal blue WF of the industrial subsectors

Rysunek 5. Pięć najniższych wewnętrznych niebieskich WF w podsektorach przemysłowych

The internal direct WF and virtual WF

The direct WF quantifies the water used in production processes within the supply chain. It provides a straightforward measure of water consumption during manufacturing operations. The highest water consumption per kilogram of product occurs in the chemical minerals mining subsectors, amounting to 13,430 m^3/kg, followed by fertilizer and nitrogen (1,391 m^3/kg), and refined petroleum products (800 m^3/kg). Conversely, the textiles and rubber products subsectors demonstrate the lowest product W (1 m^3/kg for both).

In contrast, virtual WF estimations reveal the amount of water used for internal electricity consumption, including heating, cooling and employee consumption within the facility, as detailed in Eq. (6). Figures 6 and 7 show the highest WF of electricity consumption and domestic usage within these industrial subsectors, respectively. The basic chemicals subsector leads in electricity consumption with 9 m^3/MWh, followed by the vegetable & animal oils subsector (8 m^3/MWh). Meanwhile, the detergents & perfumes subsector exhibits the highest employee WF with 219 m^3/employee, followed by the fertilizer & nitrogen subsector (126 m^3/employee) annually. Variations in these values stem from differences in the number of employees, workdays per week, employees per shift, hours per shift, and individual employee's water consumption per shift among the subsectors. Table 7 in the SI provides a comprehensive overview of the internal product WF, energy WF, and employee WF across the entire sector.

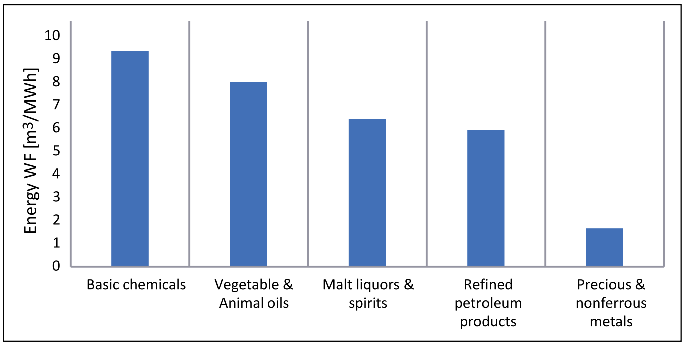

Figure 6. The 5 highest internal energy WF of the industrial subsectors

Rysunek 6. Pięć najwyższych wewnętrznych wartości WF dla energii w podsektorach przemysłowych

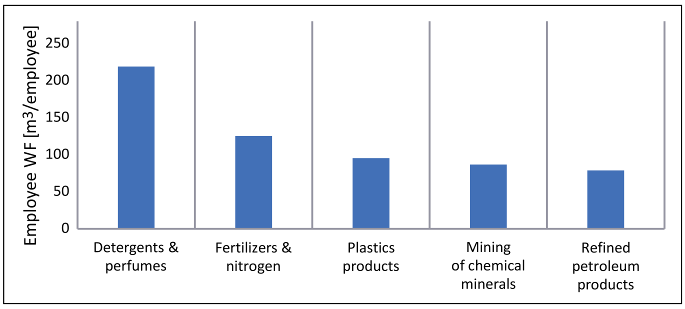

Figure 7. The 5 highest internal employee WF of the industrial subsectors

Rysunek 7. Pięć najwyższych wewnętrznych WF dla pracowników w podsektorach przemysłowych

The total internal grey WF of industrial subsectors

Figure 8 displays the 5 highest grey WF subsectors among 28 industrial subsectors. The results reveal that the refined petroleum products subsector has the highest water pollution rate with nearly 1,193 m^3 of greywater per unit of production. This subsector is among the major consumers of water, contributing a significant share of 86% of the industrial water consumption and pollution (MWI & GTZ, 2004; European Environment Agency, 2014). The previous value is higher due to the existence of the cooling towers and air conditioning units in this subsector, as the temperature reaches very high degrees during operations (JPRC). Additionally, the process of refining oil uses large volumes of water, therefore, significant amounts of wastewater are generated (0.4–1.6 times the volume of processed oil) (Fica-Piras, 2000). The next largest grey WF is the basic chemicals subsector with 805 m^3/kg of product, followed by the stone cutting and finishing subsector with 586 m^3/kg.

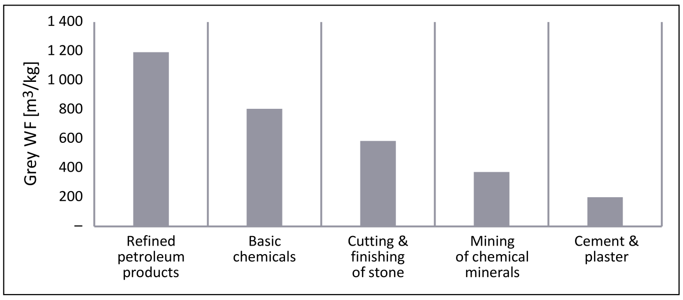

Figure 8. The 5 highest internal grey WF of industrial products

Rysunek 8. Pięć najwyższych wewnętrznych szarych WF dla produktów przemysłowych

Xu et al. (2017) demonstrate that the chemical industry & chemical production subsector had the highest grey WF with a value of 10,840 MCM, followed by the petroleum processing subsector with 3,729 MCM. These high values are due the subsectors' massive water extraction rates, thus producing significant amounts of wastewater. Regarding the stone cutting subsector, a large amount of wastewater is generated due to the washing process. Table 6 in SI displays the blue and grey WF at the subsector level, ordered according to the ISIC number.

Discussion

Among the 28 industrial subsectors, the mining of chemical minerals subsector had the highest internal blue WF, followed by the fertilizers and nitrogen subsector. In contrast, the highest grey WF was found in the refined petroleum products subsector, followed by basic chemicals subsector. The lowest internal blue WF was observed in the chemical products subsector, followed by the tobacco, extraction of petroleum & natural gas and textile subsectors. Further, the lowest internal grey WF was seen in the rubber products subsector, followed by the tobacco subsector. These findings provide insight into which industrial subsectors would benefit most from water use efficiencies-related policies. They also indicate which industries would provide greater environmental and economic benefits if their products were imported rather than exported, and vice versa.

As shown, the mining of chemical and fertilizer minerals subsector has the highest internal blue WF, with about 13,517 m^3 of freshwater per kg of produced product. This number indicates that the most water-intensive industries include nine large companies, representing about 86% of the total amount of industrial water usage. Referring to Table 5 in the SI, five mining companies are classified among the nine largest in Jordan. Since the industrial subsectors grouped similar factories under one category, the total water consumption volumes from these five mining factories were collected and placed into one category: mining of chemical and fertilizer minerals subsector. This demonstrates the large difference in blue WF, as shown previously in Figure 4. A study conducted by Xu et al. (2017) stated that the chemical industry and production subsector had the highest blue WF out of 25 different subsectors with a value of 9,855 MCM, while the petroleum processing subsector was 2,394 MCM, exemplifying a significant decrease between the two values.

Regarding the energy WF of Jordan's industrial subsectors, the calculations help determine which subsectors would benefit from increasing their use of renewable energy sources to decrease their energy WF. Currently, Jordan's use of renewable energy sources is low, accounting for less than 1% of electricity generation. Of the 16.5 MW produced by renewable energy resources, 60.4% is hydropower, 21.1% biomass, 9.7% PV (solar), and 8.8% wind (RCREEE, 2012). Despite these figures, industrial subsectors with the highest energy WF should be encouraged to use renewable energy sources in order to mitigate the total WF of these subsectors.

In order to enhance the overall efficiency of industrial water use, advanced water use technologies should be developed to maximize water resource utilization during industrial production. Government subsidies can incentivize producers who successfully conserve industrial water. Wang et al. (2018) suggest implementing a multistep water pricing method, where water prices increase with each increment of water consumption, to significantly enhance water-use efficiency and promote water resource conservation. Moreover, stricter government regulations can improve the environmental efficiency of industrial water usage by addressing water pollution and promoting the development of industrial wastewater treatment equipment and technologies. Industrial wastewater should undergo careful treatment, either through physical or environmentally sustainable chemical methods, and then released into the natural environment or used for agricultural purposes, subject to regulatory checks and tests by environmental authorities. Similarly, incentives and subsidies should be offered to industrial producers adopting environmentally friendly production technologies (Wang et al., 2018).

Water conservation strategies must target water-intensive sectors. As stated by Pereira et al. (2012), achieving water savings in both industrial and commercial sectors can be challenging without substantial incentives. Changes in the operations and production processes often require capital investment. Additionally, industries are asked to pay a certain amount for their effluent releases and water consumption. Therefore, the incentives must be substantial enough to ensure a shift in industry practices, which may vary across different industries.

Conclusion

Upon applying the methodologies adopted in this study across various industrial subsectors and analyzing the results, several conclusions emerge. Overall, the internal blue WF for the entire industrial sector, regardless of subsector type, notably increased w between 2011 and 2013, reaching 915 m^3 per unit of production in 2013. Concurrently, the associated grey WF peaked at 202 m^3 per unit of production in the year 2011.

Given the increasing interest in advancing alternative and innovative water resource solutions, the study's findings highlight multiple pathways for water management policies in Jordan. Policymakers can leverage these findings to enhance the water use sustainability of the industrial sector. Furthermore, the study provides insights into how industrial product manufacturing impacts water scarcity and pollution issues, thus facilitating the initiation of sustainable freshwater resources management practices. This approach aims to effectively manage water use within the industrial sector and contribute to the overall improvements in water resource management in Jordan.

Declarations

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Data availability statement

All data generated or analyzed during this study are included in this published article and its supplementary information file.

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Supplementary Information (SI)

Table 3. Raw dataset for gross output (*Q*, thousand JD), water consumption (*W*, thousand m^3), wastewater generation (*WW*, thousand m^3), quantitative industrial production (*Q*, kg), electricity consumption and number of employees, for 28 economic activities

Tabela 3. Surowy zestaw danych dotyczący produkcji brutto (*Q*, tysiące JD), zużycia wody (*W*, tysiące m^3), generacji ścieków (*WW*, tysiące m^3), ilościowej produkcji przemysłowej (*Q*, kg), zużycia energii elektrycznej oraz liczby pracowników, dla 28 działalności gospodarczych

Subsector	*Q* (000 JD)	*W* (000 m^3)	*WW* (000 m^3)	*Q* [kg]	Electricity [MWh]	No. of employees
Petroleum & natural gas	8,728	6	5	774	5795.4	235
Quarrying of stone	23,709	185	53	423	16361.0	757
Mining of chemical minerals	1,142,304	18,194	480	1,288	994795.1	5637
Vegetable & Animal oils	233,778	88	64	3,495	5698.7	814
Dairy products	170,283	379	153	1,470	32152.1	4447
Other food products	246,495	197	93	2,045	32433.7	4879
Malt liquors & spirits	22,873	26	11	1,807	1107.4	321
Soft drinks & waters	350,075	1,276	410	3,061	41596.2	4654
Tobacco	658,770	32	23	4,526	8096.5	1405
Textiles	30,097	36	25	3,154	3836.4	1447
Carpets & rugs	35,978	17	10	764	18531.7	651
Paper & Paper products	39,433	89	8	547	2283.8	569
Refined petroleum products	3,946,019	1,848	1,439	1,206	89927.3	3300
Basic chemicals	252,256	1,648	736	914	99774.7	1266
Fertilizers & nitrogen	375,404	1,685	37	1,126	37763.2	395
Rubber & Plastics	31,383	73	47	3,089	32411.5	1590
Paints & printing ink	170,592	85	31	3,270	12295.8	1590
Pharmaceuticals	765,012	379	144	2,587	72377.0	2691
Detergents & perfumes	221,984	286	94	2,069	17344.9	240
Chemical products	43,884	26	14	1,194	4511.4	6868
Rubber products	2,587	3	3	1,881	883.2	142
Plastics products	367,297	493	144	1,900	119252.7	3965
Cement & plaster	348,655	490	112	560	90956.4	2114
Concrete	248,360	711	92	4,580	24681.9	6145
Cutting & finishing of stone	90,426	1,303	811	1,385	71008.7	5010
Basic iron & steel	451,034	367	257	1,371	287399.3	1994
Precious & non-ferrous metals	61,685	58	30	1,307	13344.7	419
Other manufacturing	11,501	16	10	412	1143.4	337
Sources: DOS, 2014; DOS, 2015a; DOS, 2016; DOS, 2015b; Department of Statistics' Website a; Department of Statistics' Website b						

Table 4. Average export value, average export quantity and virtual water export volume

Tabela 4. Średnia wartość eksportu, średnia ilość eksportowana i wolumen eksportu wirtualnej wody

Subsector	Export Value* [JD]	Export Quantity* [kg]	Export Water [m^3]
Petroleum & natural gas	2,029,262	1,166,058	25,222,435
Quarrying of stone	–	–	–
Mining of chemical minerals	–	–	–
Vegetable & Animal oils	8,339,682	9,347,703	405,139,807
Dairy products	16,696,599	7,292,007	2,229,353,059
Other food products	–	–	–
Malt liquors & spirits	9,126,723	12,649,345	534,336,743
Soft drinks & waters	22,070,447	124,822,090	62,281,649,884
Tobacco	30,445,911	8,535,086	138,571,591
Textiles	22,871,533	5,847,452	136,938,538
Carpets & rugs	6,859,641	5,425,970	168,401,713
Paper & Paper products	123,299,414	107,684,764	18,612,368,849
Refined petroleum products	–	–	–
Basic chemicals	294,776,292	936,289,891	1,451,463,787,741
Fertilizers & nitrogen	747,070,698	655,824,425	1,016,868,967,612
Rubber & Plastics	–	–	–
Paints & printing ink	41,304,683	49,642,106	2,039,111,075
Pharmaceuticals	391,237,633	17,102,510	2,819,643,220
Detergents & perfumes	64,681,756	108,421,613	39,848,892,352
Chemical products	40,440,103	191,579,864	4,017,236,443
Rubber products	480,829	655,357	12,218,522
Plastics products	154,329,289	116,970,120	22,008,215,919
Cement & plaster	18,240,375	371,876,947	314,228,994,008
Concrete	3,448,517	49,853,452	12,310,297,552
Cutting & finishing of stone	–	–	–
Basic iron & steel	120,236,934	196,466,193	43,050,573,860
Precious & non-ferrous metals	75,420,546	9,530	716,770
Other manufacturing	–	–	–
* Source: Department of Statistics' Website b			

Table 5. Companies with the highest water consumption in the industrial sector

Tabela 5. Przedsiębiorstwa o największym zużyciu wody w sektorze przemysłowym

No.	Industry	Governorate
1	Aqaba Thermal Power Station	Aqaba
2	Jordan Phosphate Mines (fertilizer)	Aqaba
3	Arab Potash Company	Karak
4	Phosphate Mines – Wadi Al-Abyad	Karak
5	Jordan Cement Company	Mafraq, Balqa & Ma'an
6	Jordan Phosphate Mines (Shediya)	Ma'an
7	Jordan Phosphate Mines (Hassa)	Tafiela
8	Jordan Petroleum Refinery Company	Zarqa
9	Al Hussein Power Station	Zarqa
Sources: MWI & GTC, 2004; Tabieh and Al-Horani, 2010		

Table 6. Total analysis results for blue WF and grey WF

Tabela 6. Całkowite wyniki analizy dla WF niebieskiego i WF szarego

ISIC	Subsector	Blue WF [m³/kg]	Grey WF [m³/kg]
0610	Petroleum & natural gas	15	7
0810	Quarrying of stone	168	126
0891	Mining of chemical minerals	13,517	372
1040	Vegetable & Animal oils	25	18
1050	Dairy products	202	104
1079	Other food products	110	45
1101	Malt liquors & spirits	36	6
1104	Soft drinks & waters	365	134
1200	Tobacco	11	5
1392	Textiles	16	8
1393	Carpets & rugs	18	13
1701	Paper & Paper products	158	14
1920	Refined petroleum products	885	1,193
2011	Basic chemicals	745	805
2012	Fertilizers & nitrogen	1,517	33
2013	Rubber & Plastics	23	15
2022	Paints & printing ink	32	10
2100	Pharmaceuticals	109	56
2023	Detergents & perfumes	322	45
2029	Other chemical products	10	11
2211	Other rubber products	17	1
2220	Plastics products	112	76
2394	Cement & plaster	645	200
2395	Concrete	227	20
2396	Cutting & finishing of stone	805	586
2410	Basic iron & steel	32	188
2420	Precious & non-ferrous metals	52	23
3290	Other manufacturing	50	24

Table 7. Total internal product WF, energy WF and employees WF

Tabela 7. Całkowity wewnętrzny WF produktu, WF energetyczny i WF pracowników

Subsector	WF of product [m³/kg]	WF of energy [m³/MWh]	WF of employees [m³/employee]
Petroleum & natural gas	2	0.01	13
Quarrying of stone	99	0.01	69
Mining of chemical minerals	13430	0.40	87
Vegetable & Animal oils	9	8.00	8
Dairy products	188	0.90	13
Other food products	99	1.30	10
Malt liquors & spirits	5	6.00	25
Soft drinks & waters	351	0.70	14
Tobacco	3	0.30	8
Textiles	1	0.70	14
Carpets & rugs	8	0.20	10
Paper & Paper products	147	1.30	11

cont. Table 7/cd. Tabela 7

Subsector	WF of product [m^3/kg]	WF of energy [m^3/MWh]	WF of employees [m^3/employee]
Refined petroleum products	800	6.00	79
Basic chemicals	707	9.00	28
Fertilizers & nitrogen	1391	1.00	126
Rubber & Plastics	2	0.90	20
Paints & printing ink	20	0.20	12
Pharmaceuticals	91	1.20	17
Detergents & perfumes	102	1.30	219
Chemical products	8	0.60	1
Rubber products	1	0.70	16
Plastics products	16	0.70	95
Cement & plaster	614	0.70	30
Concrete	213	0	14
Cutting & finishing of stone	766	0.70	38
Basic iron & steel	10	1.10	21
Precious & non-ferrous metals	16	1.70	34
Other manufacturing	9	0.15	41

Table 8. Description for the major industrial subsectors indicated in this study
Tabela 8. Opis głównych podsektorów przemysłowych wskazanych w niniejszym badaniu

ISIC Code	Economic Activity
0610	*Extraction of crude petroleum* This class includes: • extraction of crude petroleum oils • extraction of bituminous or oil shale and tar sand • production of crude petroleum from bituminous shale and sand • processes to obtain crude oils: decantation, desalting, dehydration, stabilization etc.
0620	*Extraction of natural gas* This class includes: • production of crude gaseous hydrocarbon (natural gas) • extraction of condensates • draining and separation of liquid hydrocarbon fractions • gas desulphurization • mining of hydrocarbon liquids, obtained through liquefaction or pyrolysis
0810	*Quarrying of stone, sand and clay* This class includes: • quarrying, rough trimming and sawing of monumental and building stone such as marble, granite, sandstone etc. • quarrying, crushing and breaking of limestone • mining of gypsum and anhydrite • mining of chalk and uncalcined dolomite • extraction and dredging of industrial sand, sand for construction and gravel • breaking and crushing of stone and gravel • quarrying of sand • mining of clays, refractory clays and kaolin
0891	*Mining of chemical and fertilizer minerals* This class includes: • mining of natural phosphates and natural potassium salts • mining of native sulphur • extraction and preparation of pyrites and pyrrhotite, except roasting • mining of natural barium sulphate and carbonate (barytes and witherite), natural borates, natural magnesium sulphates (kieserite) • mining of earth colours, fluorspar and other minerals valued chiefly as a source of chemicals • guano mining

cont. Table 8/cd. Tabela 8

ISIC Code	Economic Activity
1040	*Manufacture of vegetable and animal oils and fats* This class includes the manufacture of crude and refined oils and fats from vegetable or animal materials, except rendering or refining of lard and other edible animal fats. This class includes: • manufacture of crude vegetable oils: olive oil, soya-bean oil, palm oil, sunflower-seed oil, cotton-seed oil, rape, colza or mustard oil, linseed oil etc. • manufacture of non-defatted flour or meal of oilseeds, oil nuts or oil kernels • manufacture of refined vegetable oils: olive oil, soya-bean oil etc. • processing of vegetable oils: blowing, boiling, dehydration, hydrogenation etc. • manufacture of margarine • manufacture of melanges and similar spreads • manufacture of compound cooking fats • manufacture of non-edible animal oils and fats • extraction of fish and marine mammal oils • production of cotton linters, oilcakes and other residual products of oil production
1050	*Manufacture of dairy products* This class includes: • manufacture of fresh liquid milk, pasteurized, sterilized, homogenized and/or ultra heat treated • manufacture of milk-based drinks • manufacture of cream from fresh liquid milk, pasteurized, sterilized, homogenized • manufacture of dried or concentrated milk whether or not sweetened • manufacture of milk or cream in solid form • manufacture of butter • manufacture of yoghurt • manufacture of cheese and curd • manufacture of whey • manufacture of casein or lactose • manufacture of ice cream and other edible ice such as sorbet
1079	*Manufacture of other food products n.e.c.* This class includes: • decaffeinating and roasting of coffee • production of coffee products • manufacture of coffee substitutes • blending of tea and mate • manufacture of extracts and preparations based on tea or mate • manufacture of soups and broths • manufacture of special foods • manufacture of spices, sauces and condiments • manufacture of vinegar • manufacture of artificial honey and caramel • manufacture of perishable prepared foods
1101	*Distilling, rectifying and blending of spirits* This class includes: • manufacture of distilled, potable, alcoholic beverages: whisky, brandy, gin, liqueurs, "mixed drinks" etc. • blending of distilled spirits • production of neutral spirits
1104	*Manufacture of soft drinks; production of mineral waters and other bottled waters* This class includes: • manufacture of non-alcoholic beverages, except non-alcoholic beer and wine • production of natural mineral waters and other bottled waters • manufacture of soft drinks
1200	*Manufacture of tobacco products* This division includes the processing of an agricultural product, tobacco, into a form suitable for final consumption. This class includes: • manufacture of tobacco products and products of tobacco substitutes: cigarettes, cigarette tobacco, cigars, pipe tobacco, chewing tobacco, snuff • manufacture of "homogenized" or "reconstituted" tobacco • stemming and redrying of tobacco

cont. Table 8/cd. Tabela 8

ISIC Code	Economic Activity
1311	*Preparation and spinning of textile fibres* This class includes: • preparatory operations on textile fibres • spinning and manufacture of yarn or thread for weaving or sewing, for the trade or for further processing • manufacture of paper yarn
1392	*Manufacture of made-up textile articles, except apparel* This class includes: • manufacture, of made-up articles of any textile material, including of knitted or crocheted fabrics • manufacture of made-up furnishing articles • manufacture of the textile part of electric blankets • manufacture of hand-woven tapestries • manufacture of tire covers
1393	*Manufacture of carpets and rugs* This class includes: • manufacture of textile floor coverings • manufacture of needle-loom felt floor coverings
1701	*Manufacture of pulp, paper and paperboard* This class includes: • manufacture of bleached, semi-bleached or unbleached paper pulp by mechanical, chemical (dissolving or non-dissolving) or semi-chemical processes • manufacture of cotton-linters pulp • removal of ink and manufacture of pulp from waste paper • manufacture of paper and paperboard intended for further industrial processing • further processing of paper and paperboard • manufacture of handmade paper • manufacture of newsprint and other printing or writing paper • manufacture of cellulose wadding and webs of cellulose fibres • manufacture of carbon paper or stencil paper in rolls or large sheets
1920	*Manufacture of refined petroleum products* This class includes the manufacture of liquid or gaseous fuels or other products from crude petroleum, bituminous minerals or their fractionation products. Petroleum refining involves one or more of the following activities: fractionation, straight distillation of crude oil, and cracking. This class includes: • production of motor fuel: gasoline, kerosene etc. • production of fuel: light, medium and heavy fuel oil, refinery gases such as ethane, propane, butane etc. • manufacture of oil-based lubricating oils or greases, including from waste oil • manufacture of products for the petrochemical industry and for the manufacture of road coverings • manufacture of various products: white spirit, Vaseline, paraffin wax, petroleum jelly etc. • manufacture of hard-coal and lignite fuel briquettes • manufacture of petroleum briquettes • blending of biofuels, i.e. blending of alcohols with petroleum (e.g. gasohol)
2011	*Manufacture of basic chemicals* This class includes: • manufacture of liquefied or compressed inorganic industrial or medical gases • manufacture of dyes and pigments from any source in basic form or as concentrate • manufacture of chemical elements • manufacture of inorganic acids except nitric acid • manufacture of alkalis, lyes and other inorganic bases except ammonia • manufacture of other inorganic compounds • manufacture of basic organic chemicals • manufacture of distilled water • manufacture of synthetic aromatic products • roasting of iron pyrites • manufacture of products of a kind used as fluorescent brightening agents or as luminophores • enrichment of uranium and thorium ores and production of fuel elements for nuclear reactors
2012	*Manufacture of fertilizers and nitrogen compounds* This class includes: • manufacture of fertilizers • manufacture of associated nitrogen products • manufacture of potting soil with peat as main constituent • manufacture of potting soil mixtures of natural soil, sand, clays and minerals

cont. Table 8/cd. Tabela 8

ISIC Code	Economic Activity
2013	*Manufacture of plastics and synthetic rubber in primary forms* This class includes the manufacture of resins, plastics materials and non-vulcanizable thermoplastic elastomers, the mixing and blending of resins on a custom basis, as well as the manufacture of non-customized synthetic resins. This class includes: • manufacture of plastics in primary forms • manufacture of synthetic rubber in primary forms • manufacture of mixtures of synthetic rubber and natural rubber or rubber-like gums (e.g. balata) • manufacture of cellulose and its chemical derivatives
2022	*Manufacture of paints, varnishes and similar coatings, printing ink and mastics* This class includes: • manufacture of paints and varnishes, enamels or lacquers • manufacture of prepared pigments and dyes, opacifiers and colours • manufacture of vitrifiable enamels and glazes and engobes and similar preparations • manufacture of mastics • manufacture of caulking compounds and similar non-refractory filling or surfacing preparations • manufacture of organic composite solvents and thinners • manufacture of prepared paint or varnish removers • manufacture of printing ink
2100	*Manufacture of pharmaceuticals, medicinal chemical and botanical products* This class includes: • manufacture of medicinal active substances to be used for their pharmacological properties in the manufacture of medicaments: antibiotics, basic vitamins, salicylic and O-acetylsalicylic acids etc. • processing of blood • manufacture of medicaments • manufacture of chemical contraceptive products for external use and hormonal contraceptive medicaments • manufacture of medical diagnostic preparations, including pregnancy tests • manufacture of radioactive in-vivo diagnostic substances • manufacture of biotech pharmaceuticals • manufacture of chemically pure sugars • processing of glands and manufacture of extracts of glands etc. • manufacture of medical impregnated wadding, gauze, bandages, dressings etc. • preparation of botanical products (grinding, grading, milling) for pharmaceutical use
2023	*Manufacture of soap and detergents, cleaning and polishing preparations, perfumes and toilet preparations* This class includes: • manufacture of organic surface-active agents • manufacture of soap • manufacture of paper, wadding, felt etc. coated or covered with soap or detergent • manufacture of crude glycerol • manufacture of surface-active preparations • manufacture of cleaning and polishing products • manufacture of perfumes and toilet preparations
2029	*Manufacture of other chemical products n.e.c.* This class includes: • manufacture of propellant powders • manufacture of explosives and pyrotechnic products, including percussion caps, detonators, signalling flares etc. • manufacture of gelatine and its derivatives, glues and prepared adhesives, including rubber-based glues and adhesives • manufacture of extracts of natural aromatic products • manufacture of resinoids • manufacture of aromatic distilled waters • manufacture of mixtures of odoriferous products for the manufacture of perfumes or food • manufacture of photographic plates, films, sensitized paper and other sensitized unexposed materials • manufacture of chemical preparations for photographic uses
2211	*Manufacture of rubber tyres and tubes; retreading and rebuilding of rubber tyres* This class includes: • manufacture of rubber tyres for vehicles, equipment, mobile machinery, aircraft, toy, furniture and other uses • manufacture of inner tubes for tyres • manufacture of interchangeable tyre treads, tyre flaps, “camelback” strips for retreading tyres etc. • tyre rebuilding and retreading

cont. Table 8/cd. Tabela 8

<table>
<tr><th>ISIC Code</th><th>Economic Activity</th></tr>
<tr><td>2220</td><td>Manufacture of plastics products
This class includes:
• manufacture of semi-manufactures of plastic products
• manufacture of finished plastic products
• manufacture of plastic articles for the packing of goods:
• manufacture of builders’ plastics ware
• manufacture of plastic tableware, kitchenware and toilet articles
• cellophane film or sheet
• manufacture of resilient floor coverings, such as vinyl, linoleum etc.
• manufacture of artificial stone (e.g. cultured marble)
• manufacture of plastic signs (non-electrical)</td></tr>
<tr><td>2394</td><td>Manufacture of cement, lime and plaster
This class includes:
• manufacture of clinkers and hydraulic cements, including Portland, aluminous cement, slag cement and superphosphate cements
• manufacture of quicklime, slaked lime and hydraulic lime
• manufacture of plasters of calcined gypsum or calcined sulphate
• manufacture of calcined dolomite</td></tr>
<tr><td>2395</td><td>Manufacture of articles of concrete, cement and plaster
This class includes:
• manufacture of precast concrete, cement or artificial stone articles for use in construction
• manufacture of prefabricated structural components for buildings or civil engineering of cement, concrete or artificial stone
• manufacture of plaster articles for use in construction
• manufacture of building materials of vegetable substances (wood wool, straw, reeds, rushes) agglomerated with cement, plaster or other mineral binder
• manufacture of articles of asbestos-cement or cellulose fibre-cement
• manufacture of other articles of concrete, plaster, cement or artificial stone
• manufacture of powdered mortars
• manufacture of ready-mix and dry-mix concrete and mortars</td></tr>
<tr><td>2396</td><td>Cutting, shaping and finishing of stone
This class includes:
• cutting, shaping and finishing of stone for use in construction, in cemeteries, on roads, as roofing etc.
• manufacture of stone furniture</td></tr>
<tr><td>2410</td><td>Manufacture of basic iron and steel
This class includes:
• operation of blast furnaces, steel converters, rolling and finishing mills
• production of pig iron and spiegeleisen in pigs, blocks or other primary forms
• production of ferro-alloys
• production of ferrous products by direct reduction of iron and other spongy ferrous products
• production of iron of exceptional purity by electrolysis or other chemical processes
• production of granular iron and iron powder
• production of steel in ingots or other primary forms
• remelting of scrap ingots of iron or steel
• production of semi-finished products of steel
• manufacture of hot-rolled and cold-rolled flat-rolled products of steel
• manufacture of hot-rolled bars and rods of steel
• manufacture of hot-rolled open sections of steel
• manufacture of steel bars and solid sections of steel by cold drawing, grinding or turning
• manufacture of open sections by progressive cold forming on a roll mill or folding on a press of flat-rolled products of steel
• manufacture of wire of steel by cold drawing or stretching
• manufacture of sheet piling of steel and welded open sections of steel
• manufacture of railway track materials (unassembled rails) of steel
• manufacture of seamless tubes, pipes and hollow profiles of steel, by hot rolling, hot extrusion or hot drawing, or by cold drawing or cold rolling
• manufacture of welded tubes and pipes of steel, by cold or hot forming and welding, delivered as welded or further processed by cold drawing or cold rolling or manufactured by hot forming, welding and reducing</td></tr>
<tr><td>2420</td><td>Manufacture of basic precious and other non-ferrous metals
This class includes:
• production of basic precious metals:
• production and refining of unwrought or wrought precious metals: gold, silver, platinum etc. from ore and scrap</td></tr>
</table>

cont. Table 8/cd. Tabela 8

ISIC Code	Economic Activity
2420	• production of precious metal alloys • production of precious metal semi-products • production of silver rolled onto base metals • production of gold rolled onto base metals or silver • production of platinum and platinum group metals rolled onto gold, silver or base metals • production of aluminium from alumina • production of aluminium from electrolytic refining of aluminium waste and scrap • production of aluminium alloys • semi-manufacturing of aluminium • production of lead, zinc and tin from ores • production of lead, zinc and tin from electrolytic refining of lead, zinc and tin waste and scrap • production of lead, zinc and tin alloys • semi-manufacturing of lead, zinc and tin • production of copper from ores • production of copper from electrolytic refining of copper waste and scrap • production of copper alloys • manufacture of fuse wire or strip • semi-manufacturing of copper • production of chrome, manganese, nickel etc. from ores or oxides • production of chrome, manganese, nickel etc. from electrolytic and aluminothermic refining of chrome, manganese, nickel etc., waste and scrap • production of alloys of chrome, manganese, nickel etc. • semi-manufacturing of chrome, manganese, nickel etc. • production of mattes of nickel • production of uranium metal from pitchblende or other ores • smelting and refining of uranium
3290	*Other manufacturing n.e.c.* This class includes: • manufacture of protective safety equipment • manufacture of brooms and brushes, including brushes constituting parts of machines, hand-operated mechanical floor sweepers, mops and feather dusters, paint brushes, paint pads and rollers, squeegees and other brushes, brooms, mops etc. • manufacture of shoe and clothes brushes • manufacture of pens and pencils of all kinds whether or not mechanical • manufacture of pencil leads • manufacture of date, sealing or numbering stamps, hand-operated devices for printing, or embossing labels, hand printing sets, prepared typewriter ribbons and inked pads • manufacture of globes • manufacture of umbrellas, sun-umbrellas, walking sticks, seat-sticks • manufacture of buttons, press-fasteners, snap-fasteners, press-studs, slide fasteners • manufacture of cigarette lighters • manufacture of articles of personal use: smoking pipes, scent sprays, vacuum flasks and other vacuum vessels for personal or household use, wigs, false beards, eyebrows • manufacture of miscellaneous articles: candles, tapers and the like; bouquets, wreaths and floral baskets; artificial flowers, fruit and foliage; jokes and novelties; hand sieves and hand riddles; tailors' dummies; burial caskets etc. • taxidermy activities
Source: United Nations, 2008	

Haneen DARWISH, M.Sc.
Independent researcher at the Department of Civil Engineering
Jordan University of Science and Technology
Ar-Ramtha, P.O. Box 3030, Irbid 22110, Jordan
E-mail: *hhdarwish15@eng.just.edu.jo*

Samer TALOZI, Ph.D.
Associate professor at the Department of Civil Engineering
Jordan University of Science and Technology
Ar-Ramtha, P.O. Box 3030, Irbid 22110, Jordan
E-mail: *samerbse@just.edu.jo*