

Article

Estimation of Carbon Monoxide, Sulfur Oxides, Nitrogen Oxides, Volatile Organic Compounds, and Particulate Matters Emission Due to Cryptocurrency Miners' Activity in Iran

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Abstract: Nowadays, electricity consumption has increased worldwide due to the activity of cryptocurrency miners. Much of Iran's electricity is generated by fossil fuel power plants. So, generating more electricity means producing more air pollutants in Iran. There is not sufficient information about the effects of cryptocurrency mining on Iran's air pollution. This study aims to estimate the amount of carbon monoxide (CO), sulfur oxides (SO_x), nitrogen oxides (NO_x), volatile organic compounds (VOCs), and particulate matter (PM) emitted by Iran's power plants when they generate extra electricity for cryptocurrency miners. In this study, we firstly estimated the amount of fuel used for the electricity needed for cryptocurrency miners. Then, the amounts of emitted NO_x, CO, VOCs, SO_x, and total PM for generation of such electricity were estimated via the guidelines of the European Environment Agency for emission inventory estimation. The results showed that an on average of 3530, 1547, 103, 11, and 35 tons of NO_x, CO, VOCs, SO_x, and total PM, respectively, have been emitted into the atmosphere in Iran annually.

Keywords: cryptocurrencies; air pollution; emission inventory; fossil fuel power plants



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1. Introduction

As a result of fast industrialization and economic expansion, air pollution is growing. The rising use of fossil fuels, the proliferation of motor vehicles, the growth of global aviation operations, shipping, and building are all contributing to the rise in air pollution concentrations. Cryptocurrency mining has recently been chastised for its carbon footprint [1]. Higher levels of air pollution hurt human and animal health, increasing the risk of skin, heart, brain, and reproductive system disorders [2]. Pollutants in the air also wreak havoc on regulatory immune responses [3]. Therefore, it is necessary to find a rapid solution to reduce the air pollution problem.

Cryptocurrencies are a type of digital asset and are usually managed in a decentralized manner [4]. One of the first famous cryptocurrencies was Bitcoin, which was created and released in 2009 by a person using the pseudonym Satoshi Nakamoto [5]. After Bitcoin, many more cryptocurrencies, such as Ethereum and Tether, were established. The current statistics say that between 4.5 and 10% of the world's mining for cryptocurrencies is performed in Iran [6,7]. A large amount of electricity is required to mine cryptocurrencies [8]. It is estimated that about 15,000 MW of electricity is used worldwide for the mining of cryptocurrencies [9]. To legally extract cryptocurrencies in Iran, a license must be obtained from the Ministry of Energy of Iran. The electricity used to mine cryptocurrencies in Iran is divided into two parts: legal and illegal cryptocurrency mining.

There are different estimations for the total electricity used for the extraction of cryptocurrencies in Iran. Up to May 2021, the Ministry of Energy of Iran has already issued

licenses to supply 320 MW of cryptocurrency mining units [9]. The reports show that only some of licensed units for cryptocurrency mining have currently been activated, and between them they consume around 200 MW of electricity [9]. The amount of electricity consumed for legal cryptocurrency mining in Iran is estimated to be between 200 and 300 MW (on average 250 MW) [7,9]. Additionally, the consumption of electricity for illegal cryptocurrency mining in this country is between 400 and 1200 MW (on average 800 MW) [7,9]. It seems that the total electricity used for both the legal and illegal mining of cryptocurrencies in Iran is from 600 to 1500 MW (on average 1050 MW). The average world cost of electricity is about 13.31 cents per kWh and it means that nearly USD 80,000,000 is used annually to mine various cryptocurrencies in Iran. Although many different means are applied to generate electricity, the most important method is the use of power plants that consume fossil fuel energies. Many and varied air pollutants, such as carbon dioxide CO₂, CO, SO_x, NO_x, VOCs, and PM, are generally emitted into the atmosphere during the burning of fossil fuels in power plants. Consequently, there is a direct relationship between electricity usage and the emission of air pollutants. Nowadays, the amount of electricity usage is increased due to cryptocurrency miners' activities. Power plants should increase the amount of electricity generation to provide the extra electricity needed for cryptocurrency miners. More electricity generation means more emission of air pollutants. It was estimated that the indirect CO₂ emission of cryptocurrency miners is around 80.43 million tons of CO₂, which is 0.24% of global CO₂ emissions [10]. Although many studies can be found on the air pollution status in Iran, the relationship between the mining of cryptocurrencies in Iran and air pollution has not been investigated yet. Additionally, there is no scientific estimation of the total amount of air pollutants that are emitted into the atmosphere due to the activities of cryptocurrency miners in Iran. In this study, the amounts of CO, SO_x, NO_x, VOCs, and PM emitted from total Iranian fossil fuel power plants to generate the electricity required for the mining of cryptocurrencies has been estimated. The results of this study can help the Iranian government to decide whether the limitation or expansion of cryptocurrency mining in Iran is needed.

2. Methodology

The reports showed that 25.4% of electricity in Iran is generated by renewable energies or without fossil fuels usage in combined cycle power plants, which means that they do not emit any air pollutants [11]. On the other hand, about 74.6% of electricity is directly generated using fossil fuel power plants [11]. The majority of Iran's fossil fuel power plants use natural gas as their energy source. However, in some cases, within short periods other fuels, such as diesel fuel and mazut, are replaced with natural gas in some power plants, thereby increasing the amount of air pollutants emitted. It was reported that only around 6 power plants out of 123 sometimes use mazut as their energy source [12]. Another report shows that nearly 6% of electricity in Iran is generated by mazut [13]. Additionally, only 0.5% of the total amount of electricity generated in Iran is produced by diesel power plants [14]. This information shows that the most significant fuel used in Iran's power plants is natural gas. The Ministry of Energy of the Islamic Republic of Iran is currently trying to reduce the amount of time it is taking to replace mazut with natural gas in power plants to decrease the quantity of air pollutants emitted. Between 21 March 2019 and 21 March 2020, 6 billion liters of diesel fuel, 3.5 billion liters of mazut, and 67 billion m³ of natural gas were consumed in Iran's thermal power plants [13,15]. In this study, it is assumed the periods in which that power plants use diesel fuel and mazut as energy sources are too short to have a significant effect on the quantity of air pollutants emitted at the national level. Approximately 0.37% to 0.57% of total natural gas has been used for the generation of electricity for the activities of legal cryptocurrency miners. Additionally, 0.74% to 2.22% of total natural gas has been used for the activities of illegal cryptocurrency miners. It can be concluded that the total natural gas used to mine cryptocurrencies in Iran should be between 1.11% and 2.78%. Table 1 shows the amount of natural gas that is used for both illegal and legal cryptocurrency miners. The total quantity of natural gas used to

generate electricity for cryptocurrency miners in Iran was estimated to be between 844 and 2111 million m³. Nearly 563 to 1689 million m³ and 281 to 422 million m³ of natural gas were used to generate electricity for illegal and legal cryptocurrency miners, respectively.

Table 1. The amount of natural gas used for legal and illegal cryptocurrency miners in Iran.

| The Used Natural Gas for Legal Cryptocurrency Miners | The Used Natural Gas for Illegal Cryptocurrency Miners | The Used Natural Gas for Both Legal and Illegal Cryptocurrency Miners |
|--|--|---|
| 281 to 422 million m ³ | 563 to 1689 million m ³ | 844 to 2111 million m ³ |

Equation (1) was used to calculate the amounts of various air pollutants emitted due to the activity of cryptocurrency miners.

$$C_{Air\ pollutant} = \frac{F \times 8600 \times 4184}{1,000,000,000} \times EF_{Air\ pollutant} \times 0.746 \quad (1)$$

where $C_{Air\ pollutant}$ is the emission rate of a certain air pollutant in g, F is the amount of fuel energy used for the generation of electricity needed by cryptocurrency miners in GJ, and $EF_{Pollutant}$ is the emission factor of a particular air pollutant in g/GJ, and 0.746 is the share of fossil fuel electricity energy in Iran. Based on the statistics employed by the European Environment Agency, if a power plant operates with natural gas as its fuel, the emission factors are as follows: for NO_x, 89 g/GJ of energy produced; CO is 39 g/GJ of energy produced; VOCs are 2.6 g/GJ of energy produced; SO_x constitutes 0.281 g/GJ of energy production; PM is 0.89 g/GJ of energy produced; PM₁₀ 0.89 g/GJ of energy produced and PM_{2.5} 0.89 g/GJ of energy produced [16]. The above emission factors are for situations where the power plant is not equipped with air pollution control systems. In this study, it is assumed that none of Iran's power plants are equipped with air pollution control systems. Each m³ of natural gas has 8600 Kcalories energy [17]. In total, Iran's power plants used 67 billion m³ of natural gas, which means 57.62×10^{13} Kcalories energy. However, only 1.11% to 2.78% of natural gas is used to mine cryptocurrencies in Iran; therefore, the total electrical energy used by cryptocurrency miners in Iran can be estimated to be from 7.26222×10^{12} to 1.81556×10^{13} Kcalories, which is equivalent to 30 to 76 gigajoule (GJ) (it should be noted that each kilocalorie is equal to 4184 Joule). Then, the estimated electrical energy was replaced instead of F in Equation (1). Additionally, the emission factor for each air pollutant was replaced instead with $EF_{Pollutant}$. Then, the amount of $C_{Air\ pollutant}$ was calculated for each air pollutant.

3. Results and Discussion

The results show that 2020 to 5040 tons (on average 3530 tons) of NO_x are annually emitted into the atmosphere due to the legal and illegal activity of cryptocurrency miners in Iran, and that 672 to 1010 (on average 841 tons) and 1340 to 4030 tons (on average 2690 tons) of this emitted NO_x are due to legal and illegal activities, respectively (see Figure 1). NO_x are chemical molecules created when oxygen and nitrogen react with each other at high temperatures, primarily during the combustion of fuels such as oil, diesel, gas, and organic waste. Combustion processes in the electrical power plants are a suitable place to form NO_x. NO_x has both direct and indirect health impacts on humans. Breathing difficulties, headaches, persistently decreased lung function, eye discomfort, lack of appetite, and corroded teeth are all possible side effects. It can have an indirect impact on humans by destroying the ecosystems both in the seas and on land, killing animals and plants [18].

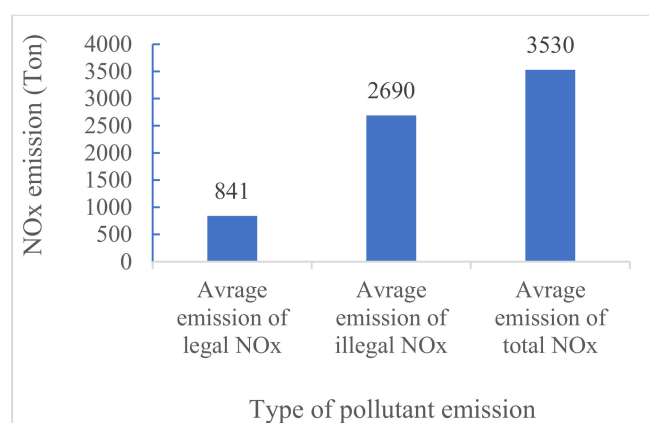


Figure 1. The amount of NO_x emitted due to the mining of cryptocurrencies in Iran.

Figure 2 shows that 2.1 to 3.1 tons (on average 2.7 tons), and 4.2 to 12.7 tons (on average 8 tons) of legal and illegal SO_x are annually emitted into the atmosphere, respectively, due to cryptocurrency miners' activity in Iran. High levels of SO_x can irritate the eyes nose, throat, and lungs and inflame the respiratory system, especially during strenuous physical exercise [19].

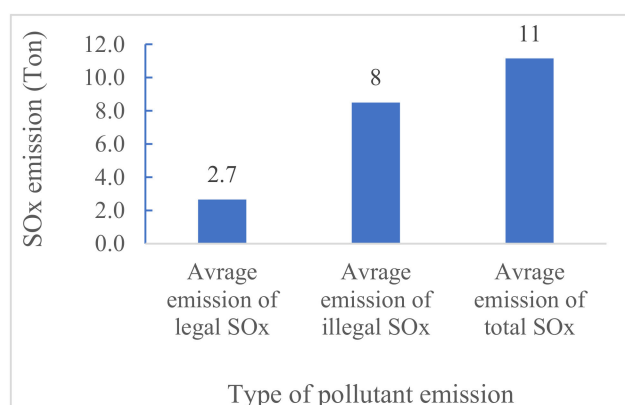


Figure 2. The amount of SO_x emitted due to the mining of cryptocurrencies in Iran.

Figure 3 shows that cryptocurrency miners are responsible for nearly 2210 to 8840 tons (on on average 1547 tons) of CO emissions in Iran. The amounts of CO emitted due to legal and illegal cryptocurrency miners are estimated at 295 to 442 tons (on average 368 tons) and 5890 to 1770 tons (on average 1179 tons), respectively. CO poisoning may happen quickly and without warning, causing loss of consciousness and subsequent suffocation. CO poisoning can cause headaches, tiredness, dizziness, sleepiness, and nausea as well as constriction across the chest. Angina patients may experience sudden chest discomfort [20].

The results illustrate that 58 to 147 tons (on average 103 tons) of VOCs are also annually emitted into the atmosphere of Iran by generating electricity for use by cryptocurrency miners. The amounts of legal and illegal VOCs emission caused by the activities of cryptocurrency miners are 6 to 10 (on average 8 tons) and 13 to 40 (on average 27 tons), respectively (see Figure 4). Organic substances with a high vapor pressure at room temperature are known as VOCs. They have a low boiling point that permits them to evaporate quickly. Most of the VOCs are dangerous for human health [21].

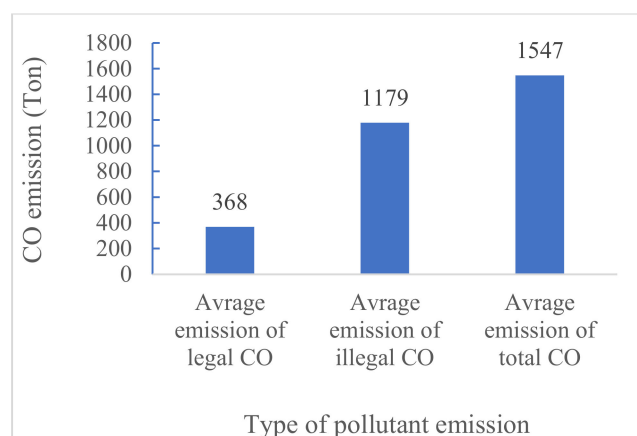


Figure 3. The amount of CO emitted due to the mining of cryptocurrencies in Iran.

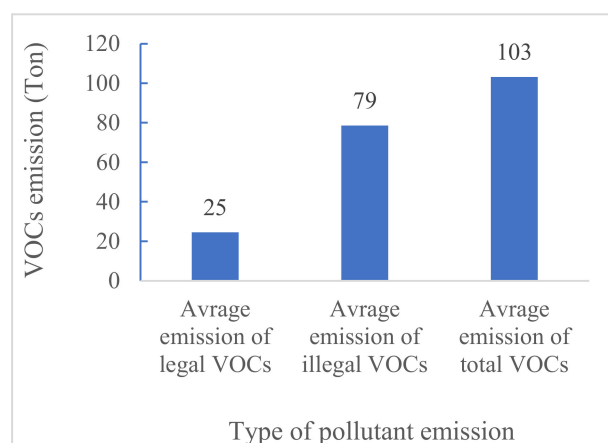


Figure 4. The amount of VOCs emitted due to the mining of cryptocurrencies in Iran.

The average total emissions of PM are estimated to be between 20 to 50 tons (on average 35 tons). The amounts of PM emitted due to electricity use via legal and illegal cryptocurrency miners in Iran are 6 to 10 tons (on average 8 tons) and 13 to 40 tons (on average 35 tons), respectively (see Figure 5). PM inhalation can cause early mortality in patients with heart or lung illness, nonfatal heart attacks, irregular heartbeat, worsened asthma, reduced lung function, and increased respiratory symptoms.

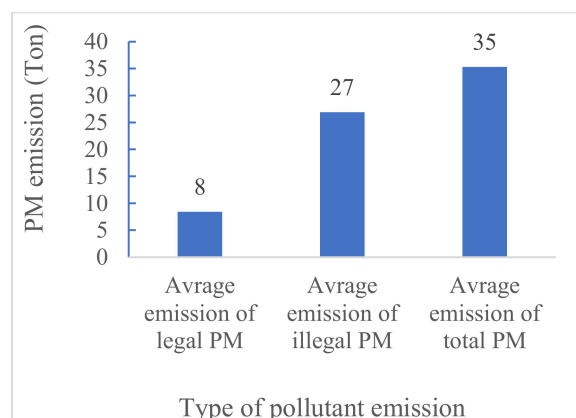


Figure 5. The amount of PM emitted due to the mining of cryptocurrencies in Iran.

It was reported that the yearly quantities of CO, VOCs, NO_x, SO_x, and PM₁₀ released by on-road mobile sources in Isfahan, one of the biggest cities in Iran, were 267,600, 12,600,

20,300, 300, and 2300 tons, respectively, in 2018 [22]. It seems that the amounts of NO_x emissions due to cryptocurrency miners in Iran are nearly 9.9% to 24.8% of the total on-road mobile sources found in Isfahan. Moreover, the levels of CO, VOCs, SO_x , and PM emitted due to cryptocurrency miners' activities in Iran are 0.82% to 3.3%, 0.45% to 1.16%, 0.7% to 1%, and 0.86% to 2.17%, respectively, of the quantities emitted in Isfahan from on-road mobile sources. The amounts of air pollutants emitted due to the activity of cryptocurrency miners in Iran are compared in Figure 6.

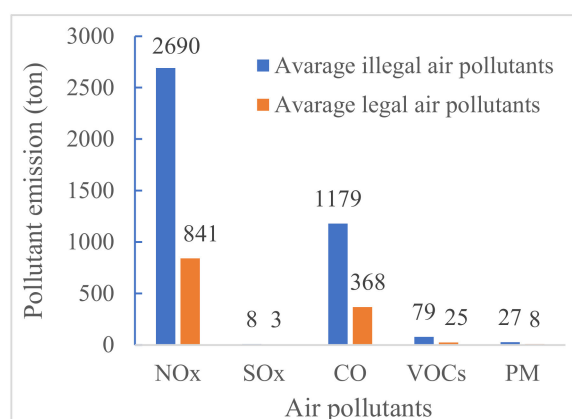


Figure 6. The comparison of average legal and illegal air pollutants emitted due to the activities of cryptocurrency miners in Iran.

4. Conclusions

Cryptocurrency miners are distributed throughout Iran and utilize electricity across the country. Iranian power plants must generate extra electricity to support these cryptocurrency miners. The generation of this extra electricity causes the annual average emission of 3530, 1547, 103, 11, and 35 tons of NO_x , CO, VOCs, SO_x , and total PM, respectively, to be emitted into the atmosphere in Iran. It seems that the pollutants emitted due to both legal and illegal cryptocurrency miners' activities in Iran do not have a significant share in the air pollution observed in Iranian cities. The results of this study can help the Iranian government to decide whether the limitation or expansion of cryptocurrency mining in Iran is needed.

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or comparable ethical standards. All procedures performed in this study involving animals followed the ethical standards of the institution or practice at which the studies were conducted.

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