



Impact of second baghdad south gas power plant on contamination of soil and plants at the university of baghdad site with some heavy metals

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Received: 01 July 2025; Revised: 16 August 2025; Accepted: 22 September 2025; Published: 30 October 2025

Abstract

Impact of second gas power plant in South Baghdad, near University of Baghdad, on soil and plant contamination at university site with some heavy metals (Ni, Pb, and Cd) resulting from gases, smoke, and volatile vapors was studied. Soil samples and samples of cultivated plants and growing trees were taken at the university at a distance of 250 and 500 meters from the center of station in four directions. Soil samples were also taken from sites covering most of university area and at different distances with a depth of 0-30 cm. Comparative samples were also taken within a distance of 1-2 km from station with three replicates. Results indicated the following: 1-Concentrations of total and available Lead, Cadmium, and Nickel in soil of University of Baghdad varied at different sites depending on their proximity or distance from second South Baghdad Gas Power Plant for generating electrical power and their location relative to the main street at university. Highest concentration of total Lead was found in a site in front of Faculty of Science building near main street, 27.72 mg kg⁻¹, for Cadmium 57.50 mg kg⁻¹ at site inside Faculty of Agricultural Engineering Sciences research station in front of college deanship located 1000 m to north of e station, total Nickel 148.00 mg kg⁻¹ at site next to station's garage, which is 250 m to south of station. concentrations of elements in plant, they reached for Lead, 5.10 mg kg⁻¹ dry matter in sites in front of Faculty of Political Science, next to the research station of Faculty of Agricultural Engineering Sciences, near sanitary landfill area, and at a distance of 250 m, for Cadmium, 2.26 mg kg⁻¹ dry matter in sites inside research station of Faculty of Agricultural Engineering Sciences, in front of Deanship building, for Nickel, 2.90 mg kg⁻¹ dry matter in site next to private garage in the station, which is 250 m away. 2- Concentrations of total and available Lead in soil and plants did not exceed the internationally permissible limits, therefore soil and plants are not contaminated with Lead. All soils and plants are considered contaminated with Ccadmium, as they exceeded internationally permissible limits for this element in soil and plants. Concentrations of total Nickel in soil exceeded the internationally permissible limits, therefore soil is considered contaminated with Nickel,

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DOI: 10.70102/IJARES/V5I2/5-2-26

while Nickel concentrations in plants did not exceed internationally permissible limits, therefore plants are not contaminated with Nickel. This study highlights the necessity of continuous monitoring and adopting phytoremediation or soil management practices to reduce heavy metal accumulation around the power plant.

Keywords: Soil and plant pollution, Heavy metals, Second Baghdad south gas power plant

Introduction

Environmental pollution is one of most serious problems of our time. Soil contamination with heavy metals has significantly increased in recent decades. This pollution comes from both human and natural sources. Human sources include industrial facilities and power plants that use fossil fuels for energy generation, agriculture, workshops, waste incineration, traffic, smelting, mining, and others. Natural sources include rock decomposition, volcanic eruptions, and more.

Soil pollution is a physical, chemical, or biological disturbance or imbalance in soil resulting from human or natural activity, consciously or unconsciously, followed by direct or indirect damage to public health of humans and environment, including its living organisms, natural resources, and economic properties (Al-Jumaili and Ahmed, 2018). Heavy metals are natural elements found in environment or food and are called heavy because their atomic weights are five times the weight of water or more, their density or specific weight is more than 5 grams cm^{-3} or more (Al-Omar, 2000; Suciú *et al.*, 2008) and atomic number is greater than 20 (Minnikova *et al.*, 2016; Raskin *et al.*, 1994), or elements with atomic weights greater than atomic weight of Iron (55.85 g) (Saad and Rahima, 2023),

or elements with a specific weight greater than 5 g/cm^3 (Suciú *et al.*, 2008). Heavy metal pollution is one of most dangerous forms of environmental pollution and one of most important problems affecting human health (Balaid, 2019). It is a serious environmental problem due to its non-degradability and long biological half-life (Mahnayeh *et al.*, 2022; Ahmed *et al.*, 2009). Some of these elements are essential for life, their low concentrations are not toxic, but they become toxic if their concentration in body increases to point that they interfere with growth of body's cells and various systems (Mahnaia *et al.*, 2022). Accumulation of heavy metals in agricultural soils is a growing concern due to its relation to food safety, or its leaching into groundwater and surface water, which may lead to potential health risks. Heavy metals accumulate in plants and organisms and enter human food chain (Varol and Sen, 2009).

Excessive accumulation of heavy metals in plants leads to changes in physiological processes, leading to plant poisoning by disrupting plant enzymes and causing mutations due to their effects on DNA. Competition also occurs between essential plant nutrients and heavy metals on surfaces of ion exchange sites, which leads to reduced plant growth and affects the

photosynthesis process (Shah *et al.*, 2009; Saleem *et al.*, 2018).

Dandash, 2005; AL-Anbari, AL-kaissi and Al-Ameri, 2013 explained that most influential source of environmental pollution is electric power generation stations, especially those that use fossil fuels. It is known that one of most air pollutants in cities is from electric power generation and conversion facilities, then the clean industry sectors and raw materials industries. (Hassan, 2012; Al-Ghalbi, 2016) pointed to increase in Lead contamination of soil and plants in Dora/Baghdad area due to smoke and fumes emanating from Dora power station. Thermal or steam power plants use heavy fuel oil to generate energy. This fuel enters directly into thermal units, noting that at beginning of operation, gas oil (diesel) is used. As for gas stations, they process heavy fuel and then use it in the gas units, this fuel enters directly into thermal units, noting that at beginning of operation, gas oil (diesel) is used. As for gas stations, they process heavy fuel and then use it in gas units.

Al-Hakak, 2021 in his study on impact of the Wasit Thermal Power Plant on contamination of soil, water and plants in surrounding areas with some heavy metals, indicated an increase in total concentration of Nickel, Cadmium and Lead in soil, exceeding internationally permissible limits, as it reached 309.42, 14.20 and 168.63 mg kg⁻¹ for aforementioned elements, respectively. (Al-Ziyadi, 2022; Al-Ani, 2000) confirmed in his study of fuel combustion waste in a thermal power

plant that fuel combustion waste contains a high concentration of elements Cr, Pb, Ni, and Fe. Hassan (2012) pointed to an increase in Lead concentrations in environment of Dora area/Baghdad and attributed this to industrial facilities in area such as Dora refinery, Dora power station and increase in number of cars that use gasoline and gases they produce that pollute environment due to their containing hydrocarbons and vapors of various heavy metals. The importance of research lies in fact that heavy metals accumulated in soil represent a real danger facing humans, due to their relationship with food safety, or their arrival through leaching into groundwater and surface water, which may lead to potential health risks. Heavy metals also accumulate in plants and organisms that enter human food chain. Since agricultural soils in many parts of world are polluted with these elements. Research aims to know the effect of gases, smoke and volatile vapors from second gas-fired power station south of Baghdad, near University of Baghdad, on pollution of soil and plants inside University of Baghdad with some heavy metals (Ni, Pb, Cd) based on concentrations of critical heavy metals in soil and plants.

Materials and Methods

To determine the contamination status of gases, smoke, and volatile vapors from second South Baghdad Gas Power Plant, adjacent to University of Baghdad, and contamination of soil and plants at the University of Baghdad site with some heavy metals (Ni, Pb, and Cd). Soil samples were taken at a distance of 250

and 500 meters from center of station in four directions. Soil samples were also taken from agricultural experiment stations of College of Agricultural Engineering Sciences and other sites within university (included most of university area) and at different distances according to selected sites within university site at a depth of 0-30 cm, comparative samples were taken within a distance of 1-2 km from station, with three replicates. Samples were also taken from plants grown in agricultural experiment stations of College of Agriculture and growing trees at university. The sampling sites were purposefully selected in relation to the proximity of the gas power plant and the wind direction, to capture potential gradients of contamination intensity. The 250 m and 500 m distances were selected to represent a near-field and mid-field location the most likely influenced by airborne emissions and particulate deposition from the power station. Sampling sites on the university campus were further chosen to examine spatial distribution and possible dispersion of pollutants influenced by topography and vegetation cover. Furthermore, reference sites (i.e., control sites) at a distance of 1-2 km from the station served to provide baseline reference concentrations to better distinguish the direct impacts of power plant emissions from naturally occurring soil and plant metal concentrations. Available and total concentration of above heavy metals in soil and plants was estimated. The available heavy metals were extracted from soil by chelating compound (DTPA) Diethylene triamine pentaacetic acid according to

method of (Lindsay & Novella (1978), then they were measured by Atomic Absorption Spectrometer, total content of heavy metals under investigation was estimated after digesting samples by mixture of two acids ($\text{HClO}_4 - \text{H}_2\text{SO}_4$). This was done by taking one gram of air-dried sample, sieved with a sieve with a diameter of 2 mm, and placing it in a 25 ml Pyrex bottle, then, 4 ml of concentrated sulfuric acid (H_2SO_4) was added and left for 24 hours. then, samples were air-cooled and 2 ml of perchloric acid (HClO_4) was added at a temperature of $180\text{ }^\circ\text{C}$ for 2-3 hours. Samples were placed on a hot plate until color changed from dark brown to clear, colorless. Volume was completed to 25 ml with distilled water and filtered with Whatman No. 42 filter paper, then measurement was carried out to estimate heavy metals using an Atomic Absorption Spectrometer. Dry and ground plant samples were digested in a same way mentioned above by using concentrated Nitric acid instead of Sulfuric acid, concentration of heavy metals in it was determined as mentioned above.

Results and Discussion

Concentrations of total and available Lead in soil and plants at sites within University of Baghdad located north and northeast of second Baghdad South Gas Power Plant.

Table 1 shows presence of significant differences in concentration of total Lead in soil of University of Baghdad for different locations north and northeast of second South Baghdad gas station for generating electric power, as highest concentration of total Lead in

location in front of College of Science building near main street reached 27.72 mg kg^{-1} . This is due to the exhaust fumes of various types of vehicles that use fossil fuels (gasoline and kerosene), which contain high concentrations of Lead due to its addition to fuel to improve quality of fuel and increase efficiency of use, in addition to proximity of site to the station, as distance was 1100 m, this shows effect of station's waste on total Lead concentration in soil. These results are consistent with what was found by (Srivastava *et al.*, 2022), which showed that human activities, such as mining, vehicle exhausts, lead-acid battery industries, municipal and industrial waste dumps, sewage, and house dust, are responsible for soil Lead contamination, while lowest concentration of total Lead was inside garage of College of Agricultural Engineering Sciences, which leads to electronic computer located in front of playgrounds of College of Physical Education, which amounted to 11.70 mg kg^{-1} . This is due to distance from station site (1500 m), thus station's impact on it is relatively small, in addition, site is far from main street, and thus vehicles have a small impact on total Lead concentration.

Concentration of available Lead, significant differences were found in soil of University of Baghdad sites, as highest available concentration of Lead reached 7.62 mg kg^{-1} soil in soil in front of College of Science building near main street, 1100 m from station. This is

consistent with total concentration of Lead in soil of this site, which is highest concentration in soil of University of Baghdad sites. These results are consistent with what was found by (Saleem *et al.*, 2018), which showed an increase in Lead pollution in soil, water and air due to various human activities. The use of leaded gasoline in cars may also be one of main sources of Lead pollution in soil. Lowest concentration of available Lead in soil was 4.28 mg kg^{-1} in soil of the garage of Faculty of Agricultural Engineering Sciences located in front of playgrounds of Faculty of Physical Education. This was consistent with lowest total concentration of Lead in this location. This is consistent with what was found by Tayeh *et al.* (2024), who showed that burning of fossil fuels in pollution sources increased concentration of Nickel and Lead in soil close to source, and it decreased further we moved away from the source. When comparing concentrations of total Lead in different locations with critical limits for total Lead in soil according to World Food and Health Organization (WHO/FAO, 2007; Skorbiłowicz and Rogowska, 2021; Zanetta-Colombo *et al.*, 2024), we find that they did not exceed critical limits for element in soil. The variation in concentration of available Lead in soil of different locations may be due to several factors, including distance and proximity to power plant or main street at university, where cars pass, causing Lead pollution from their exhaust fumes.

Table 1: Concentrations of total and available Lead in soil and plants at sites within University of Baghdad located north and northeast of second South Baghdad Gas Station.

No.	Location within the university	Geographical location	Distance from station (meters)	Lead concentration in soil (mg kg^{-1})		Lead concentration in plants (mg kg^{-1} dry matter)
				Total	Available	
1	(In front of the Faculty of Political Science) next to research station of Faculty of Agricultural Engineering Sciences, near sanitary landfill area.	North of station	250	20.50	7.11	5.10
2	(In front of the Faculty of Political Science) next to research station of Faculty of Agricultural Engineering Sciences, near sanitary landfill area	North of station	500	17.22	6.20	4.18
3	Inside the research station of Faculty of Agricultural Engineering Sciences (P) near sanitary landfill area.	North of station	800	15.75	6.11	4.91
4	At the end of main street of university coming from university entrance when turning next to old lake of university which is currently dry.	North of station	1000	14.00	6.63	4.19
5	Inside research station of Faculty of Agricultural Engineering Sciences, in front of college deanship.	North of station	1000	23.75	6.26	4.19
6	In front of Faculty of Science building, near the street.	North of station	1100	27.72	7.62	4.80
7	In front of Genetic Engineering Institute, near main street.	North of station	1200	25.25	6.23	4.20
8	In front of Faculty of Engineering, next to main road inside university.	North of station	1200	21.50	5.99	3.71
9	Inside the greenhouse of Department of Soil Sciences and Water Resources - Faculty of Agricultural Engineering Sciences, in front of library inside Agricultural Research Station B.	Northeast of station	1200	12.50	4.31	3.16
10	Outside greenhouse of Department of Soil Sciences and Water Resources - Faculty of Agricultural Engineering Sciences, in front of library inside Agricultural Research Station B.	Northeast of station	1250	14.40	4.41	3.36
11	In front of College of Agricultural Engineering Sciences building, Department of Soil Sciences and Water Resources, after College of Agricultural Engineering Sciences garage, near paved road.	Northeast of station	1000	19.62	5.90	3.60
12	In front of College of Education for Girls building, next to street leading to second building, College of Agricultural Engineering Sciences.	Northeast of station	1300	18.00	6.58	4.42
13	Inside garage of Faculty of Agricultural Engineering, near street leading to computer, in front of Faculty of Physical Education playgrounds.	Northeast of station	1500	11.70	4.28	3.03
Critical limits mg kg^{-1} (WHO/FAO, 2007)				100		5.00
LSD 0.05				0.799*	0.412*	0.453*

Lead concentration in plants

Table 1 showed significant differences in Lead concentration in plants, with highest concentration reaching 5.10 mg kg^{-1} dry matter in sites in front of

College of Political Science, next to research station of College of Agricultural Engineering Sciences, near sanitary landfill area, at a distance of 250 m. The distance from station had a significant impact on increasing Lead

concentration inside plant, this is due to fallout from gaseous waste from plant due to proximity of site. This is consistent with what was found by (Khalaf *et al.*, 2024), who showed that increased accumulation of Lead in plants is due to increased fuel consumption, increased lead emissions into the air, and increased lead concentration in soil. Lowest concentration of Lead in plant was 3.03 mg kg^{-1} dry matter at site inside garage of College of Agricultural Engineering Sciences near street leading to electronic computer site in front of College of Physical Education playgrounds (comparison). This may be due to distance from station (1500 m). It is noted that it was consistent with lowest concentration of total and available Lead in soil. The site's distance from station affected decrease in Lead concentrations. This is consistent with what (Al-Rikabi, 2023) found, which indicated an increase in concentration of Cadmium and Lead in sites close to pollution source due to gaseous emissions and resulting vapors, and decreased with distance from source. These concentrations did not exceed internationally permissible critical limits for Lead in plants.

Concentrations of total and available Lead in soil and vegetation located south and east of the second Baghdad South Gas Power Plant.

Table 2 shows total Lead concentration in sites south and east of station, where highest total Lead concentration reached 16.75 mg kg^{-1} next to station's garage, distance from station was 250 m, which had a clear effect on highest concentration due to fallout from

station's gaseous waste. This is consistent with what was found by (Bedeeh and Fakher, 2022) who showed that Lead concentration increases in areas close to pollution sources. Lowest concentration was 10.70 mg kg^{-1} in soil inside research station of Faculty of Agricultural Engineering Sciences inside computer building. This is due to distance from station (2300 m), and thus station's effect on it is relatively small, as well as location's distance from main street, thus effect of vehicles on Lead concentration is small.

Table 2 shows presence of significant differences in concentration of available Lead in the sites within University of Baghdad, south and east of station, as highest concentration of available Lead (6.09 mg kg^{-1}) was in soil located next to station's garage, distance of soil from station was 250 m, where it played an important role in increasing concentration through fallout from station's gaseous waste and its effects, it was observed that it was consistent with total Lead concentration. This is consistent with what was found by (Bhardwaj *et al.*, 2020) who indicated that spatial distribution of heavy metals (Lead and Cadmium) increases in most of contaminated samples located near thermal power plants and mining area.

Lowest concentration of available Lead reached 3.18 mg kg^{-1} in soil located inside research station of College of Agricultural Engineering Sciences inside electronic computer building at a distance of 2300 m. It is noted that it is consistent with lowest concentration of total Lead. Distance from station affected concentration of Lead, whether

total or available, due to fallout from gaseous waste and its effect, as well as its distance from public street. This is consistent with what was found by (Long *et al.*, 2021), who showed that in areas with high traffic density, vehicle emissions and tire and brake wear lead to soil and dust contamination with Lead and Cadmium, levels decrease with distance from source.

Lead concentration in plants

Table 2 shows significant differences in Lead concentration in plants. Highest Lead concentration in plants (3.93 mg

kg⁻¹ dry matter) was found at site next to station's garage, 250 m away from station. Highest concentration of total and available Lead for this site was consistent with the effect of distance from station and role of fallout from station's gaseous waste in influencing Lead concentration. This is consistent with what was found by (Jahan *et al.*, 2024; Raj and Das, 2023), who showed that combustion of fossil fuels leads to emission of large quantities of Lead and heavy metals into environment, which causes soil and plant pollution.

Table 2: Concentrations of total and available Lead in soil and plants at sites south and east of second Baghdad South Gas Station.

No.	Location within the university	Geographical location	Distance from station (meters)	Lead concentration in soil (mg kg ⁻¹)		Lead concentration in plants (mg kg ⁻¹ dry matter)
				Total	Available	
1	Next to the station's garage.	South of station	250	16.75	6.09	3.93
2	Next to a public road inside university	South of station	500	14.75	5.90	3.52
3	In front of Faculty of Agricultural Engineering Sciences apiary, near paved street.	East of station	800	13.70	5.81	3.43
4	In front of Faculty of Agricultural Engineering Sciences building, Medicinal Plants Research Unit, near the street.	East of station	1350	12.25	4.02	3.11
5	Inside the research station of Faculty of Agricultural Engineering Sciences, inside computer building.	East of station	2300	10.70	3.18	2.27
Critical limits mg kg ⁻¹ (WHO/FAO, 2007)				100		5.00
LSD 0.05				0.589*	0.226*	0.563*

Lowest concentration of Lead in plants was at site inside research station of College of Agricultural Engineering Sciences inside electronic computer building, as it reached (2.27 mg kg⁻¹ dry matter) east of station and at a distance of 2300 m from station. It is noted that it is consistent with lowest concentration of total and available Lead in soil of site.

This is consistent with what was found by (Zwolak *et al.*, 2019), who indicated that main sources of Lead pollution in soil, plants, and air are exhaust gases from motor vehicles. These results were consistent with distance and proximity to station and public street. They did not exceed internationally permissible limits for Lead in plants.

Total and available Cadmium concentrations in soil and plants at sites north and northeast of second Baghdad South Gas Power Plant.

Table (3) indicates presence of significant differences in concentration of total Cadmium in soil, highest concentration of Cadmium 57.50 mg kg^{-1} was reached in sites within research station of College of Agricultural Engineering Sciences in front of college deanship located to north of station for a distance of 1000 m. This is consistent with what was found by (Ankush *et al.*, 2024) who indicated that industrial processes, mining activities and agricultural practices contribute significantly to environmental pollution with Cadmium. Lowest concentration of total Cadmium in soil was 32.50 mg kg^{-1} in locations inside garage of College of Agricultural Engineering Sciences near street leading to electronic computer site in front of College of Physical Education playgrounds located 1500 m northeast of station. This is consistent with what (Al-Rikabi, 2023) found, which showed that concentration of Cadmium and Lead increased in sites close to pollution source due to gaseous emissions and resulting vapors, decreased with distance from source. Total Cadmium concentrations exceeded internationally permissible limit (WHO/FAO, 2007) of 5 mg kg^{-1} , making soils contaminated with Cadmium. Table 3 shows the presence of significant differences in

concentration of available Cadmium in soil, highest concentration of available Cadmium 3.17 mg kg^{-1} was reached in sites within research station of College of Agricultural Engineering Sciences in front of college deanship located to north of station at a distance of 1000 m. It is noted that it is consistent with highest concentration of total Cadmium in that site. This is consistent with what was found by (Men *et al.*, 2018) who noted that high concentration of Cadmium may be attributed to combustion of coal and fuel, as well as exhaust gases and atmospheric dust that settle on soils, especially urban soils, which differ from rural soils that are far from human activities and have a lower concentration of heavy metals. Lowest concentration of available Cadmium was 1.79 mg kg^{-1} in soil of sites inside garage of College of Agricultural Engineering Sciences near street leading to the electronic computer site in front of playgrounds of College of Physical Education and at a distance of 1500 m from station from northeast side of station. It was noted that it was consistent with lowest concentration of total Cadmium in that site. This is consistent with what was found by Mubeen, *et al.*, (2018), which showed that proximity of some species to pollution sources contributes to increasing accumulation of Cadmium, and it decreases further we move away from source.

Table 3: Total and available Cadmium concentrations in soil and plants at sites north and northeast of second Baghdad South Gas Plant.

No.	Location within the university	Geographical location	Distance from station (meters)	Cadmium concentration in soil (mg kg ⁻¹)		Cadmium concentration in plants (mg kg ⁻¹ dry matter)
				Total	Available	
1	(In front of the Faculty of Political Science) next to research station of Faculty of Agricultural Engineering Sciences, near sanitary landfill area.	North of station	250	51.00	3.12	2.13
2	(In front of the Faculty of Political Science) next to research station of Faculty of Agricultural Engineering Sciences, near sanitary landfill area	North of station	500	48.00	2.09	1.41
3	Inside the research station of Faculty of Agricultural Engineering Sciences (P) near sanitary landfill area.	North of station	800	46.70	2.11	1.50
4	At the end of main street of university coming from university entrance when turning next to old lake of university which is currently dry.	North of station	1000	40.00	2.02	1.33
5	Inside research station of Faculty of Agricultural Engineering Sciences, in front of college deanship.	North of station	1000	57.50	3.17	2.26
6	In front of Faculty of Science building, near the street.	North of station	1100	52.00	3.13	2.19
7	In front of Genetic Engineering Institute, near main street.	North of station	1200	47.25	2.25	1.61
8	In front of Faculty of Engineering, next to main road inside university.	North of station	1200	44.25	2.19	1.30
9	Inside the greenhouse of Department of Soil Sciences and Water Resources - Faculty of Agricultural Engineering Sciences, in front of library inside Agricultural Research Station B.	Northeast of station	1200	41.00	2.08	1.21
10	Outside greenhouse of Department of Soil Sciences and Water Resources - Faculty of Agricultural Engineering Sciences, in front of library inside Agricultural Research Station B.	Northeast of station	1250	45.50	2.09	2.25
11	In front of College of Agricultural Engineering Sciences building, Department of Soil Sciences and Water Resources, after College of Agricultural Engineering Sciences garage, near paved road.	Northeast of station	1000	42.25	2.18	1.27
12	In front of College of Education for Girls building, next to street leading to second building, College of Agricultural Engineering Sciences.	Northeast of station	1300	41.75	2.03	1.32
13	Inside garage of Faculty of Agricultural Engineering, near street leading to computer, in front of Faculty of Physical Education playgrounds.	Northeast of station	1500	32.50	1.79	0.86
Critical limits mg kg ⁻¹ (WHO/FAO, 2007)				100		5.00
LSD 0.05				2.426*	0.440*	*0.589

Cadmium concentration in plants at sites north and northeast of second Baghdad South Gas Power Plant

Table 3 shows presence of significant differences in concentration of cadmium in plant, highest concentration 2.26 mg kg^{-1} dry matter was reached in sites within research station of College of Agricultural Engineering Sciences in front of Deanship building, and it was consistent with highest concentration of total and available Cadmium in this site, as indicated by (Timothy and Williams, 2019) those who pointed out that most important sources of heavy metal emissions such as Cadmium and Lead and air pollution are combustion of fuel and coal, vehicle exhaust emissions, industrial production and energy production, waste disposal, and vehicle exhaust. Pollutants deposited in soil may be transferred to plants. Lowest concentration of Cadmium in plant was 0.86 mg kg^{-1} dry matter in locations inside garage of College of Agricultural Engineering Sciences near street leading to e electronic computer building in front of College of Physical Education playgrounds and at a distance of 1500 m from station, and it was consistent with lowest concentration of available and total Cadmium in this location.

Total and available Cadmium concentrations in soil and plants at sites south and east of second Baghdad South Gas Power Plant.

Table 4 shows significant differences in concentration of total Cadmium in soil, highest concentration (37 mg kg^{-1}) was reached at site next to station's garage and at a distance of 250 m, as fallout from station's gaseous waste played a

major role in increasing concentration. This is consistent with what was found by (Schaefer, Dennis and Fitzpatrick, 2020; Zhang *et al.*, 2017). They showed that Cadmium is transported by dust or smoke over long distances and eventually falls to the ground. It then easily accumulates in soil, enters human body through inhalation, and enters food chain after being absorbed by plants. Lowest concentration reached 12.50 mg kg^{-1} at site inside research station of College of Agricultural Engineering Sciences inside electronic computer building in northeast direction of station and at a distance of 2300 m. This is consistent with what was found by (Bard, Hussein and Al-Dajil, 2024) who indicated that reason for low concentration of Cadmium is due to absence of polluting industries at site as well as small number of cars.

Table 4 shows presence of significant differences in concentration of available cadmium in soil for sites south and east of second South Baghdad Gas Power Plant for generating electric power, highest concentration reached 2.11 mg kg^{-1} in site next to station's garage for a distance of 250 m, and it was observed that it was consistent with highest total concentration for this site, and this is consistent with what was found by (Genchi *et al.*, 2020), they showed that human activities such as fossil fuel combustion, in addition to leachate from landfill sites, agricultural lands and mining waste, especially from Zinc and Lead mines, contribute to environmental pollution with Cadmium. Lowest concentration of available Cadmium was 0.38 mg kg^{-1} at site inside research station of College of Agricultural

Engineering Sciences inside computer building, which is 2300 m away from station. It is noted that it is consistent with lowest total Cadmium concentration at this site, as well as its distance from main road. This is consistent with what was found by (Norvell and Lindsay, 1978; Maring *et al.*, 2023), who indicated that huge increase in vehicle traffic led to a huge

increase in pollution, especially some heavy metals such as Cadmium (Cd), hexavalent Chromium (Cr), Arsenic (As), and Nickel (Ni). Pollution decreases with decrease in vehicle traffic. Total Cadmium concentrations exceeded internationally permissible limits (WHO/FAO, 2007) of 5 mg kg⁻¹, and thus soil is considered to be contaminated with Cadmium.

Table 4: Concentrations of total and available Cadmium in soil and plants at sites south and east of second Baghdad South Gas Station.

No.	Location within the university	Geographical location	Distance from station (meters)	Cadmium concentration in soil (mg kg ⁻¹)		Cadmium concentration in plants (mg kg ⁻¹ dry matter)
				Total	Available	
1	Next to the station's garage.	South of station	250	37.00	2.11	1.46
2	Next to a public road inside university	South of station	500	28.75	1.89	1.27
3	In front of Faculty of Agricultural Engineering Sciences apiary, near paved street.	East of station	800	23.25	1.79	1.21
4	In front of Faculty of Agricultural Engineering Sciences building, Medicinal Plants Research Unit, near the street.	East of station	1350	17.50	1.10	0.73
5	Inside the research station of Faculty of Agricultural Engineering Sciences, inside computer building.	East of station	2300	12.50	0.89	0.38
Critical limits mg kg ⁻¹ (WHO/FAO, 2007)				100		5.00
LSD 0.05				0.486*	0.363*	*0.335

Cadmium Concentration in Plants at Sites South and East of Second Baghdad South Gas Power Plant

Table 4 indicated presence of significant differences in concentration of Cadmium in plant, highest concentration (1.46 mg kg⁻¹ dry matter) was reached at site next to station's garage, which is 250 m away from station, It may be noted that it is consistent with highest concentration of total and available Cadmium at this site and effect of fallout from gaseous waste of station on it. This is consistent with what was found by (Sharma, Nagpal and Kaur, 2018). They pointed out that contamination of agricultural crops with

heavy metals such as Cadmium is caused by power plants that lead to accumulation of these elements. Lowest concentration of Cadmium in plants was 0.38 mg kg⁻¹ of dry matter at site of College of Agricultural Engineering Sciences' research station, inside computer building. This is consistent with lowest concentration of total and available Cadmium in soil at a distance of 2300 m from station. This is consistent with what was found by (Men *et al.*, 2018; Mubeen *et al.*, 2023), who indicated that proximity of some species to pollution sources contributes to increased Cadmium accumulation, and it

decreases the further we move away from source.

Total and Available Nickel Concentrations in Soil and Vegetation at Sites North and Northeast of Second Baghdad South Gas Power Plant

Table 5 indicates presence of significant differences in concentration of total Nickel in soil at sites within the University of Baghdad located north and northeast of second South Baghdad Gas Power Plant for generating electrical power, highest concentration of total Nickel reached 111.00 mg kg⁻¹ at site within research station of College of Agricultural Engineering Sciences in front of college deanship. This is consistent with findings of (Hassan *et al.*, 2019), who showed that exposure to Nickel in agricultural soils is mainly due to overuse of pesticides, fungicides, herbicides, and fertilizers containing Nickel, as well as through burning of fossil fuels and industrial waste. Lowest concentration of total Nickel in soil at sites within the University of Baghdad located north and northeast of second South Baghdad Gas Power Plant for generating electrical power, reached 40 mg kg⁻¹ at site inside garage of College of Agricultural Engineering Sciences near street leading to electronic computer site in front of playgrounds of College of Physical Education, and it is 2000 m away from station (comparison). This is due to its distance from station, and thus distance affected concentration. This is consistent with what was found by (Tayeh and Al-Kalabi, 2024), who explained that combustion of fossil fuels in pollution sources has increased concentration of Nickel and Lead in soil

near source, and it decreases further we move away from source.

When comparing these concentrations with critical concentrations of Nickel in soil, which amount to 50.00 mg kg⁻¹ according to World Food and Health Organization (WHO, FAO, 2007), we find that all sites are contaminated with Nickel because they exceeded critical limits, except for site inside garage in College of Agricultural Engineering Sciences in front of College of Physical Education playgrounds, due to its distance from station and its effects (2000 m), total Nickel concentration in soil reached 40.00 mg kg⁻¹. Total Nickel concentrations at most sites exceeded internationally permissible limit (WHO/FAO, 2007) of 50 mg kg⁻¹, making soils Nickel contaminated. Table (5) shows presence of significant differences in the concentration of available Nickel in soil at sites within University of Baghdad located north and northeast of second South Baghdad gas station for generating electrical power, highest concentration of available Nickel reached 3.93 mg kg⁻¹ at site within research station of College of Agricultural Engineering Sciences in front of college deanship, and this was consistent with highest concentration of total Nickel in soil. These results are consistent with those found by (Huang *et al.*, 2018; Jones, 2001), who observed elevated Nickel concentrations in soils near human activities such as mining, vehicle exhaust, and agricultural activities. Lowest concentration of available Nickel in soil at sites within the University of Baghdad located north and northeast of second South Baghdad

gas-fired power plant reached 1.20 mg kg⁻¹ at the site inside garage of College of Agricultural Engineering Sciences, near street leading to computer site in front of College of Physical Education playgrounds. It was consistent with lowest concentration of total Nickel that was in same location, these results are

consistent with what was found by (Tayeh and Al-Kalabi, 2024), who explained that concentration of Nickel increases in soil through human activities and fuel combustion and decreases further we move away from source of pollution.

Table 5: Total and available Nickel concentrations in soil and plants at sites within University of Baghdad located north and northeast of second South Baghdad Gas Plant.

No.	Location within the university	Geographical location	Distance from station (meters)	Nickel concentration in soil (mg kg ⁻¹)		Nickel concentration in plants (mg kg ⁻¹ dry matter)
				Total	Available	
1	(In front of the Faculty of Political Science) next to research station of Faculty of Agricultural Engineering Sciences, near sanitary landfill area.	North of station	250	99.50	2.92	2.29
2	(In front of the Faculty of Political Science) next to research station of Faculty of Agricultural Engineering Sciences, near sanitary landfill area.	North of station	500	104.00	3.82	2.86
3	Inside the research station of Faculty of Agricultural Engineering Sciences (P) near sanitary landfill area.	North of station	800	87.50	2.86	1.68
4	At the end of main street of university coming from university entrance when turning next to old lake of university which is currently dry.	North of station	1000	78.50	2.71	1.19
5	Inside research station of Faculty of Agricultural Engineering Sciences, in front of college deanship.	North of station	1000	111.00	3.93	2.80
6	In front of Faculty of Science building, near the street.	North of station	1100	78.50	2.82	2.17
7	In front of Genetic Engineering Institute, near main street.	North of station	1200	67.00	2.68	1.20
8	In front of Faculty of Engineering, next to main road inside university.	North of station	1200	87.50	2.90	1.48
9	Inside the greenhouse of Department of Soil Sciences and Water Resources - Faculty of Agricultural Engineering Sciences, in front of library inside Agricultural Research Station B.	Northeast of station	1200	55.50	2.02	1.21
10	Outside greenhouse of Department of Soil Sciences and Water Resources - Faculty of Agricultural Engineering Sciences, in front of library inside Agricultural Research Station B.	Northeast of station	1250	71.50	2.08	1.37
11	In front of College of Agricultural Engineering Sciences building, Department of Soil Sciences and Water Resources, after College of Agricultural Engineering Sciences garage, near paved road.	Northeast of station	1000	66.00	1.95	1.20
12	In front of College of Education for Girls building, next to street leading to second building, College of Agricultural Engineering Sciences.	Northeast of station	1300	57.00	1.88	1.10
13	Inside garage of Faculty of Agricultural Engineering, near street leading to computer, in front of Faculty of Physical Education playgrounds.	Northeast of station	1500	40.00	1.20	0.91
Critical limits mg kg ⁻¹ (WHO/FAO, 2007)				100		5.00
LSD 0.05				2.779*	0.258*	0.236*

Nickel Concentrations in Plants

Table 5 indicates significant differences in Nickel concentrations in plants at sites north and northeast of second South Baghdad Gas Power Plant. Highest Nickel concentration in plants reached 2.86 mg kg^{-1} dry matter at site in front of College of Political Science, next to College of Agricultural Engineering Research Station, near sanitary landfill area and 500 m from plant. This is due to site's proximity to plant. This is consistent with findings of (Tayeh and Al-Kalabi, 2024), who demonstrated ease with which Nickel, resulting from human activities and fuel combustion, can be absorbed by plants from clayey surfaces of soil. Lowest concentration of Nickel in plants in sites within University of Baghdad located north and northeast of second South Baghdad gas station for generating electrical power, reached 0.91 mg kg^{-1} dry matter in site inside garage of College of Agricultural Engineering Sciences near street leading to electronic computer site in front of College of Physical Education playgrounds due to its distance from station (2000 m). This is consistent with what was found by (Saleh and Al-Moussawi, 2022), who indicated that concentration of Nickel increases in sites close to pollution source and decreases further we move away from source. When comparing concentration of Nickel in plants of all studied sites with critical limits for Nickel in adult plants, 67 mg kg^{-1} dry matter (WHO, FAO, 2007), we find that it did not exceed these limits. This may be due to fact that Nickel is one of essential trace elements for plants, which they need to complete

growth process, thus its concentration in plants did not exceed internationally permitted limits.

Total and Available Nickel Concentrations in Soil and Vegetation at Sites South and East of Second Baghdad South Gas Power Plant

Table (6) indicates presence of significant differences in concentration of total Nickel in soil at sites south and east of second South Baghdad Gas Power Plant for generating electrical power, highest concentration of total Nickel reached $148.00 \text{ mg kg}^{-1}$ at site next to the station's garage, which is 250 m away to south of station. It is noted the extent of effect of wind direction and distance on fallout from station's gaseous waste in increasing concentration. This is consistent with what was found by (Kosiorek and Wyszowski, 2020; Rizwan, Usman and Alsafran, 2024) who indicated that high concentration of Nickel in atmosphere is mainly due to fuel combustion, municipal waste burning, mining, and refining. Lowest concentration of total Nickel in soil in sites south and east of second Baghdad South Gas Power Plant for generating electric power, lowest concentration of total Nickel reached 56.00 mg kg^{-1} at site inside Agricultural Engineering College Research Station inside computer building and at a distance of 2300 m from station. This is due to distance from station. This is consistent with what (Saleh and Al-Moussawi, 2022) found, who showed that concentration of Nickel increases in sites close to pollution source and decreases further we move away from source.

Table 6: Total and available Nickel concentrations in soil and plants at sites south and east of second Baghdad South Gas Plant.

No.	Location within the university	Geographical location	Distance from station (meters)	Nickel concentration in soil (mg kg ⁻¹)		Nickel concentration in plants (mg kg ⁻¹ dry matter)
				Total	Available	
1	Next to the station's garage.	South of station	250	148.00	4.03	2.90
2	Next to a public road inside university	South of station	500	83.00	2.89	1.71
3	In front of Faculty of Agricultural Engineering Sciences apiary, near paved street.	East of station	800	67.00	2.80	1.43
4	In front of Faculty of Agricultural Engineering Sciences building, Medicinal Plants Research Unit, near the street.	East of station	1350	64.50	2.72	1.23
5	Inside the research station of Faculty of Agricultural Engineering Sciences, inside computer building.	East of station	2300	56.00	2.11	1.14
	Critical limits mg kg ⁻¹ (WHO/FAO, 2007)			100		5.00
	LSD 0.05			3.094*	0.260*	*0.415

Table 6 shows the presence of significant differences in concentration of available Nickel in soil at sites within University of Baghdad located south and east of second South Baghdad Gas Power Plant for generating electrical power, highest concentration of available Nickel reached 4.03 mg kg⁻¹ at site next to station's garage, this is due to its proximity to station (250 m). This is consistent with highest total Nickel concentration for this site. This is consistent with what (Farhan, 2020; Han *et al.*, 2025) found, who explained that increase in Nickel concentration in soils near pollution sources that use fossil fuels and their incomplete combustion is due to gaseous waste released into air by plant and its subsequent deposition on nearby soils. Total Nickel concentrations at all sites exceeded internationally permissible limit (WHO/FAO, 2007) of 50 mg kg⁻¹, making soils Nickel-contaminated Table 6.

Lowest concentration of available Nickel in soil in sites inside University of Baghdad located south and east of second South Baghdad gas station for generating electrical power, lowest concentration of available Nickel reached 2.11 mg kg⁻¹ at site inside research station of College of Agricultural Engineering Sciences inside electronic computer building located to east of station and a distance of 2300 m from it. This is due to location's distance from station, it is noted that it is consistent with lowest total Nickel concentration, this is consistent with what Al-Ghalbi (2016) found, which showed that Nickel concentration increases in soils near second Baghdad gas station in Al-Dura due to gaseous waste it releases into air, and it decreases further we move away from source.

Nickel concentration in plants

Table 6 indicates significant differences in Nickel concentration in plants at sites

south and east of second South Baghdad Gas Power Plant for generating electricity. Highest Nickel concentration in plants reached 2.90 mg kg^{-1} of dry matter at site next to station's private garage, which is 250 meters away. This indicates proximity to station and soil contamination. This correlation is observed with highest concentration of total and available Nickel. This is consistent with what Al-Ghalbi (2016) found, which showed that increased Nickel concentration in soil leads to increased plant uptake due to gaseous waste discharged by station, especially in areas close to it. Lowest Nickel concentration in plants is found in sites within University of Baghdad located south and east of second South Baghdad Gas Power Plant. It reached 1.14 mg kg^{-1} dry matter at site inside research station of College of Agricultural Engineering Sciences inside electronic computer building, which is 2300 m away from station. Thus, little effect of station on soil and plants is clear due to its distance from station. It is noted that it is consistent with lowest concentration of total and available Nickel in these sites. This is consistent with what (Saleh and Al-Moussawi, 2022; Abdul Latif, 2022) found, they demonstrated that Nickel concentrations increased in locations close to pollution source and decreased as one moved away from it. These concentrations did not exceed critical limits for Nickel in plants because Nickel is a micronutrient essential for plant growth, and thus element is consumed in plant growth processes.

Cadmium and Nickel showed higher accumulation near the power plant, indicating direct influence from gaseous

and particulate emissions, whereas Lead remained within safe limits. These findings suggest localized contamination patterns and highlight the need for continuous monitoring and mitigation measures around the affected zones.

Conclusions

Smoke, gases, and volatile vapors from second south Baghdad Gas Power Plant, near University of Baghdad, contaminated soil and plants at university site with Cadmium and Nickel, while Lead concentrations in soil and plants were uncontaminated. To mitigate contamination in the affected areas, it is recommended to establish green buffer zones with dense vegetation capable of absorbing and stabilizing heavy metals, and to conduct regular environmental monitoring of soil and plant samples to track pollutant accumulation over time. Moreover, phytoremediation using native plant species tolerant to Cd and Ni can serve as a sustainable remediation approach. Future research should focus on long-term monitoring of pollutant dispersion, evaluation of bioaccumulation risks in the food chain, and assessment of advanced emission control measures at the power plant to reduce future contamination.

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