Journal of Experimental Agriculture International

Volume 46, Issue 7, Page 40-46, 2024; Article no.JEAI.117172
ISSN: 2457-0591
(Past name: American Journal of Experimental Agriculture, Past ISSN: 2231-0606)

Chemical Analysis and Agricultural Utilizations of Dams Reservoir Sediments

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Authors' contributions

This work was carried out in collaboration among all authors. Author ZAAB wrote the original draft manuscript, which was edited and improved by author IIAA. All authors have read and agreed to the published version of the manuscript.

Article Information

DOI: https://doi.org/10.9734/jeai/2024/v46i72555

Open Peer Review History:
This journal follows the Advanced Open Peer Review policy. Identity of the Reviewers, Editor(s) and additional Reviewers, peer review comments, different versions of the manuscript, comments of the editors, etc are available here: https://www.sdiarticle5.com/review-history/117172

Original Research Article

Received: 20/03/2024
Accepted: 29/05/2024
Published: 03/06/2024

ABSTRACT

Sediment samples were collected from King Talal Dam (KTD) and subjected to chemical, physical, and mineralogical study to test their suitability as soil replacement. The concentration of Cadmium (Cd), Chromium (Cr), Copper (Cu), Iron (Fe), Lead (Pb), Nickel (Ni), Arsenic (As), Cobalt (Co), and Zinc (Zn) was obtained by atomic absorption spectrophotometer, and the elements phosphorus (P) and boron (B) were determined by using the spectrophotometric technique.
These elements concentration was compared with the average concentration of soil in near by area of Jordan valley, It was found that the concentration of Cu and Zn, P, Fe, Mn, and K is within the standard range for soil fertility, and the concentration of Pb, Ni, As, Co, and Cd is within the

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***Cite as:** Al-Balawna, Z. A., Abu-Abdoun, I. I., Saleh, O. Y., Khamis, A. A. M., & Al-Talb, T. M. (2024). Chemical Analysis and Agricultural Utilizations of Dams Reservoir Sediments. Journal of Experimental Agriculture International, 46(7), 40–46. https://doi.org/10.9734/jeai/2024/v46i72555*

standard range of agricultural human health safety regulation's, the highest concentration on of iron (Fe) and manganese (Mn) in sediment were found to be 1.48% and 15.0 ppm respectively. The lowest average concentration in KTD sediment was identified for cadmium (Cd) and arsenic (As) and was found to be <0.01 and <0.05 ppm respectively. The Laboratory tests carried out indicate that the water of King Talal Dam is free of heavy metals pollutants, and reservoir sediments can be used for soil replacement and amendment. It is highly recommended to keep the percentage of sediments of KTD to soil used in agriculture within the range of 25%-50%.

Keywords: Dam reservoir; soil pH; available nutrient; soil salinity; soil conditioners; heavy metals in dam sediment.

1. INTRODUCTION

Water is the main source of life on earth and since the amount of water available for use is not enough in many countries especially the third world ones, dams and reservoirs are mainly built for irrigation, power generation, flood control, and water supply. In Jordan, there are around 10 existing dams, and the number is anticipated to increase due to shortage of water and the future development in both agricultural and industrial sectors. King Talal Dam is an Earthfill dam which has been in operation since1987, it is located in the eastern heights of the kingdom, and it was built for the irrigation and electricity [1].

The agricultural utilization of sediments are the most promising alternatives due to the beneficial properties of sediments that are rich in clay, silt, organic matter, nutrients (macro- and micro nutrition), and microbial activity [2].

It is very important to have full information and analysis on the composition of the dame sediments if they are going to be used in any percentages in agricultural soil. Another aspects is the knowledge of nutrient types, and concentration level, as this will have a high impact on the quality and quantity of the plants and products [3].

The essential micronutrients for all crops are B, Cu, Fe, Mn, and Zn. Other minerals and nutrients at low concentrations that are considered essential to the growth of some plants are nickel (Ni) and cobalt (Co) [4].

Micronutrient deficiencies in crops have increased markedly in recent years due to intensive cropping, loss of topsoil by erosion, losses of micronutrients through leaching, liming of acid soils, decreased proportions of farmyard manure compared to chemical fertilizers, increased purity of chemical fertilizers, and use of marginal lands for crop production [5].

Calcareous soils present of high levels of free calcium carbonate ($CaCO_3$) and also high pH "low acidity", and the large amounts soluble salts reduce the availability of essential mineral nutrients such as Zn, Cu, Mn, Fe, B, and P that are necessary for the growth and development of crops and for quality and quantity of crops yield. Nitrogen (N), Phosphorus (P), and Potassium (K) are the essential macronutrients [6].

The objective of this study is to carry out physical and chemical analysis of present heavy metals in KTD sediments and compare it with the Jordan Valley soil of farmers to see the possibility of using sediments as fertilizers and artificial soils [7,8]. The selection of suitable reservoirs for the study is a major step in this study, then the content, nature, distribution of sediments, and physical characteristics are very essential. The weathering conditions, process, and topology will affect these properties besides water quality during the irrigation process [9].

Generally, elements susceptible to weathering will be available in high concentration, in proportion related to ions combination and solubility, this will control the mineral availability to plants and influence the quality and quantity of the production [10].

The concentration or level of major macronutrients (N, P, K) which are indispensable elements for plants will decide on sediment evaluation and suitability for the type of plants and agricultural use. It is expected that the major elements mentioned are available in higher concentrations in soil sediments having medium levels of mineral soils and parent soils in drainage sinks [11].

2. MATERIALS AND METHODS

This study was carried out at the laboratory of Jordan Valley Authority, farm Dair-Ulla dim and area 22, farm unit 91 located at Ulla, Al-Balqa.

Fig. 1. The location of soil samples collected from the bottom of King Talal Dam in Jordan Valley

Source:https://www.google.com/maps?q=king+talal+dam&rlz=1C1GGRV_enJO748JO748&um=1&ie=UTF-8&sa=X&ved=2ahUKEwjn3YWQyKn2AhUl7rsIHUAjCYEQ_AUoAnoECAIQBA

Table 1. Total trace element heavy metals and macro element concentration in KTD sediments

Lab test	Sediment 2	Sediment 3
dS/m EC1:1	1.90	2.10
pH 1:1	6.86	7.02
CaCO3 %	40	42
Total Nitrogen %	0.369	0.344
Organic Matter %	2.31	2.39
Cu Total ppm	16.71	14.88
Fe Total %	1.48	1.29
Mn Total ppm	140.00	151.00
Zn Total ppm	100.28	107.11
Cd Total ppm	<0.01	0.00
Co Total ppm	5.00	5.00
As Total ppm	<0.05	0.00
Cr Total ppm	54.00	44.30
Ni Total ppm	22.00	18.70
Pb Total ppm	0.40	0.32
Total P %	4700.00	4680.00
Total K %	1350.00	1410.00
% Clay	30.30	25.00
Silt %	42.50	35.00
Sand %	27.20	40.00
Texture Class	clay loam	clay loam

The climate of the Jordan Valley region is very dry, and semi-cool, with winter extremes, with rain in winter precipitation exceeding 30%, and in summer the temperature ranges from 38 to 39 ^oC [12,13].

2.1 Study Site

The soil samples are collected from the bottom of King Talal Dam in Jordan Valley the location is shown in Fig. 1.

2.2 Preparation of Sample

To sediment samples, preparation of 500 g weight were dried at 105 °C for two hours. Selected one gram of each sample was weighed carefully and 5 mL of concentrated nitric acid (Merck, 65.0%) was added. These samples were heated up to 80°C until near dryness, addition of acid and the process of heating were repeated two more times. Taking two composite samples of sediments from King Talal Dam. Chemical and physical tests were conducted to determine the content of heavy metals and fertilizer elements. These tests in Table 1 were conducted in the Jordan Valley Authority laboratories

Add water to the residual material, and filter the suspension using (Whatman filter Merck, 0.45 µm), then the filtrate was diluted by deionized water to a final volume of 50 m, for the analysis of B, Cu, Fe, Mn, and Zn elements.

2.3 Methods and Analysis

Weight 10.0 g from blank sample to prepare soil extraction (1:5 extract) following the procedure in method of soil analysis, [14] measure the electrical conductivity (EC) by using an electron conductivity meter (Jen way type), the pH was measured using PH- meter (METROHOM). Then weigh 25.0 g from blank to digest the soil completely with tri-acid (HF/HCl/HNO3) under a fume hood with a temperature of 160 degrees for 6 hrs for two days or till the soil solution is completely digested for heavy metal and phosphorus, potassium analysis.

3. RESULTS AND DISCUSSION

Analysis of sediment samples from the lake of King Talal Dam (KTD) (Table 1) revealed that the mean concentration of Cu, Fe, Mn, P, and Zn in sediment samples are higher than in Jordan Valley soil, while the concentration of Cd, Cr, Cu, Fe Mn, Pb, and Zn in sediment samples are lower [15].

The comparison of the mean concentrations of heavy metals in (KTD) sediment with the standard value in soil and those used for agriculture suggests that the mean concentration of Fe, Zn, Cu, and P is within the standard overrange for soil specification [16].

From Table 2 the concentrations of Cd, Pb, Ni, Co, Cr, and As are within the low standard range of agricultural soil. Accordingly, KTD sediment is suitable for plants as potting soil and as a soil conditioner. From Table 1 the abundances of toxic elements (Pb, Ni, Cr, Cd, As) are much lower than average values for mineral soils [17].

Each group of the micronutrients (Fe, Cu, Zn, Mn) sediments have similar distribution patterns of metal, the total abundances are within the high ranges despite being higher than in parent soils. These elements occur on the surface of fine-grained particles such as clay minerals, particles of Mn oxides, and organic molecules; they may be associated with Fe-Al-oxides, Manganese (Mn) is found as an insoluble oxide. Fe, Cu, Mn, and Zn have low solubility Table 1, they hardly exceed the concentration considered, accordingly, not toxic to the soils. which could be used as slow-release fertilizers. [18] Table 1 shows major macronutrient (N P K) concentrations in sediment which are important for plant nutrition.

3.1 Fertility Tests

Obtained Sediments from KTD were used as artificial soils and additives, using mixtures with various proportions of soil from Jordan Valley. Experiments were conducted with appropriate reference samples and the tested plants were selected based on economic benefit and biological suitability as indicators of substrate suitability. Using a few representative sediments from the KTD reservoir and after that compare it with another sample of commercially high-quality potting soil which is used as a reference is the basis of the conducted fertility test [19].

The results were evaluated by an empirical and dimensionless “Success Index”, which is based on the increase in plant growth, flowering, and production as shown in Table 2, which confirmed the suitability of KTD sediments for agricultural use, as they compared perfectly well with top quality commercial potting soil. When fertility experiments were conducted with pepper plants in a controlled greenhouse in these tests, for a comparative growth rate, we used first a mixture of sediments from KTD; after that a common soil from Jordan Valley nearby area a chemically inert matrix (for better physical support), under five different mixtures including; 100% soil, 75% soil + 25% sediment, 50% soil, + 50% sediment, 25% sediment + 75% soil, and 100% sediment.

Weekly measurements were carried out of the parameters such as growth rate, flowering/ fructification period, flowering open, and number/weight of fruits and reported in Table 2.

KTD chemical and mineralogical characteristics of the precipitated materials and the solubility, and precipitation of metals in reservoirs, KTD reservoirs were developed under distinct climatic conditions to find the effect of weathering conditions and metals leaching mechanisms on the fertility index of sediments.

This study here shows that it is worth evaluating the economic feasibility of removing reservoir sediments and using them for agricultural purposes to improve selected areas with scarce sandy soils. sediments could eventually yield better results because they can be used as soils on their own, but the more clayey varieties, due to high nutrient abundances, can be used as fertilizers for poor quality sandy soils [20].

Table 2. Increasing in plant growth, flowering, and plant yields

Type of plant	Growth media	Growth %	Flowering %	Yield %
Geranium Flower	100% sandy soil,	%100	%100	N/A
	75% sandy soil + 25% KTD sediment,	100%	100%	N/A
	50% sandy soil + 50% KTD sediment,	100%	100%	N/A
	25% sandy soil, + 75%KTD sediment	75%	75%	N/A
	100% KTD sediment ,	50%	50%	N/A
Pepper	100% sandy soil,	%100	%100%	8.5 kg/1m2
	75% sandy soil + 25% KTD sediment,	110%	110%	9.0 kg/1m2
	50% sandy soil + 50% KTD sediment,	110%	110%	9.5 kg/1m2
	25% sandy soil, + 75%KTD sediment	100%	100%	9.00 kg/1m2
	100% KTD sediment ,	60%	60%	7.0 kg/1m2
Eggplant	100% sandy soil,	100%	100%	10 kg/1m2
	75% sandy soil + 25% KTD sediment,	110%	110%	11.0 kg/1m2
	50% sandy soil + 50% KTD sediment,	115%	115%	12.0 kg/1m2
	25% sandy soil, + 75%KTD sediment	100%	100%	10.0 kg/1m2
	100% KTD sediment ,	70%	70%	8.0 kg/1m2

The chemical composition of sediments is very important regarding their suitability for agricultural use and as for soils in general, it is important to know about the nutrients and toxic element levels and the conditions that enhance their release and availability to plants.

If regular sediment removal from the reservoirs becomes economically feasible, the suitability for use in agriculture may ultimately solve some classical problems such as; the period of life of dam reservoirs filled with sediments; the water quality; and the shortage of soils in some regions.
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It was found that the condition of the plant is at its best when the level of King Talal Dam sediments in the soil is 25% and 50%. This could be due to this ratio provides nutrients to the plant and maintains the moisture level in the soil, and the reason for the low plant level of production when the sedimentation rate is 100% may be due to a high level of sedimentation reduces the permeability of the soil, which contributes to the high level of soil-borne diseases.

4. CONCLUSION

The reported results here support using of KTD sediment as soil fertilizer’s**.** The results of the analysis the sediment in King Talal Dam Lake show concentrations of P, Fe, Zn, Cu, and Mn, in the sediment exceed that in Jordan Valley soil. The sediment analysis showed that the total content of metals such as Pb, Cr, Cd, As, Co, and Ni is less than limits according to the soil used guidelines for agriculture.

The average content of the total Pb was 0.5 mg/kg Cd was 0.1 mg/kg As was 0.5 mg/kg Cr was 0.2 mg/kg, and Co was 0.1 mg/kg, that is about a very low level.

The average content of the total Fe was 0.5 mg/kg, Zn was 0.1 mg/kg, As was Cu mg/kg, and Mn was 0.1 mg/kg, which are about very high levels. In conclusion, it is highly recommended to use the dam sediment for agriculture as potting soil and soil conditioners.

When KTD sediments are added to enhance soil, the percentage of sediments in the soil is within the range of 25%-50%. It is preferable to add to non-calcareous soil, adding organic acids to irrigation water contributes to reducing soil basicity, this will improve the level of nutrients in the soil, and reduce damage to a calcareous soil characteristics.

ACKNOWLEDGEMENT

Support to this work from Jordan valley authority laboratories, Dair Ulla, -Al-Balqa, Jordan, (ZAA) and the Chemistry Department, university of Sharjah (IIA)is gratefully acknowledged.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

REFERENCES

1. Nidal Haddadin. Dams in Jordan current and future perspectives), Canadian Journal of Pure and Applied Sciences. 2015;9(1): 1920-3853
2. Padmaja V Karanam, Suhas P Wani , Kanwar Lal Sahrawat Ls Jangawad. Economic evaluation of sediments as a source of plant nutrients. Current Science. 2008;95(8).
3. Agnieszka Baran, Marek Tarnawski, Magdalena Urbaniak. An Assessment of Bottom Sediment as a Source of Plant Nutrients and an Agent for Improving Soil Properties. Environmental Engineering and Management Journal. 2019;18(8):1647-1656.
   DOI: 10.30638/eemj.2019.155
4. Zohuir A. Al-Balawna and Ideisan I. Abu-Abdoun. Modification of Jordanian Zeolite as Slow-release Fertilizers and Soil Conditioner. International Journal of Plant & Soil Science. 2024;36(6):364-370.
   Available:http://info.submit4journal.com/id/eprint/3616
5. Fageria NK, Baligar VC, Clark RB. Micronutrients in crop production, Advances in Agronomy. 2002;77:185-268.
6. Partner RG. Effects of bicarbonate, nitrate and other environmental factors on Iron deficiency chlorosis. A review. Journal of Plant Nutrition Journal of Plant Nutrition. 2000;23(11):1591-1606.
7. Rita Fonseca, Fernando JAS, Barriga WS. Fyfe Reversing desertification by using dam reservoir sediments as agriculture soils. Episodes. 1998;21(4).
   DOI: 10.18814/epiiugs/1998/v21i4/001
8. Fong-Zuo Lee, Jihn-Sung Lai, Tetsuya Sumi. Reservoir Sediment Management and Downstream River Impacts for Sustainable Water Resources—Case Study of Shihmen Reservoir. Water. 2022; 14(3):479.

Available:https://doi.org/10.3390/w14030479

9. Fernando António Leal Pacheco, Renato Farias do Valle Junior, Maytê Maria Abreu Pires de Melo Silva, Teresa Cristina Tarlé Pissarra, Glauco de Souza Rolim, Marília Carvalho de Melo, Carlos Alberto Valera, João Paulo Moura, Luís Filipe Sanches Fernandes. Geochemistry and contamination of sediments and water in rivers affected by the rupture of tailings dams (Brumadinho, Brazil). Applied Geochemistry. 2023;152:105644.
DOI: 10.1016/j.apgeochem.2023.105644
10. Lorra Belle Hill. The Transport and Persistence of Escherichia coli in Leachate from Poultry Litter Amended Soils. Open Journal of Soil Science. 2024;14(4)
DOI: 10.4236/ojss.2024.144015
11. Toor MD, Adnan M, Rehman FU, Tahir R, Saeed MS, Khan AU, Pareek V. Nutrients and their importance in agriculture crop production; A review. Ind. J. Pure App. Biosci. 2021;9(1):1-6.
12. Zohuir A. Al-Balawna, Ideisan I, Abu-Abdoun. The effect of sulphur powder addition on the chemical and physical properties of soil in Jordan valley. Journal of Agriculture and Environmental Sciences. 2019;8(2):42-48.
13. Zohuir A Al balawna, Ideisan I Abu-Abdoun. Effect of adding dilute sulphuric acid on calcareous soil properties in Jordan valley. Archives of Agriculture Research and Technology (AART). 2021; 2(1):1-5,
14. Dennis L. Corwin Dennis L. Corwin Scott Lesch Scott Lesch. Application of soil electrical conductivity to precision agriculture. Agronomy Journal. 2003;95(3).
DOI: 10.2134/agronj 2003.0455.
15. Mahmoud M, Abualhaija, Maisa'a Wasif Shammout, Alsharifa Hind Mohammad, Ahmad Hamed Abu Hilal, (Heavy Metals in Water and Sediments of King Talal Dam the Largest Man-Made Water Body in Jordan) Water and Energy International. 2019;62r(5):49-62.
16. Fituma Lemessa, Belay Simane, Assefa Seyoum, Girma Gebresenbet. Analysis of the concentration of heavy metals in soil, vegetables and water around the bole Lemi industry park, Ethiopia. Heliyon. 2022;8:12429.
17. Joshua O. Olowoyo, Ntebo Lion, Tshoni Unathi, Oluwaseun M. Oladeji. Concentrations of Pb and Other Associated Elements in Soil Dust 15 Years after the Introduction of Unleaded Fuel and the Human Health Implications in Pretoria, South Africa. Int J Environ Res Public Health. 2022;19(16):10238.
DOI: 10.3390/ijerph191610238
18. Islam MM, Akther SM, Wahiduzzaman M, Hossain MF, Parveen Z. Fractionation and Contamination Assessment of Zn, Cu, Fe, and Mn in the Sundarbans Mangrove Soils of Bangladesh. Soil and Sediment Contamination: An International Journal. 2023;32(7):789-811.
19. Fonseca R, Barriga FJAS, Fyfe WS. Reversing desertification by using dam reservoir sediments as agriculture soils. Episodes. 1998;21(4):218-224.
20. Espinoza-Quiñones FR, Zacarkim CE, Palacio SM, et al. Removal of heavy metal from polluted river water using aquatic macrophytes *Salvinia sp.* Brazilian Journal of Physics. 2005;35(3): 744–746.

Peer-review history:
The peer review history for this paper can be accessed here:
https://www.sdiarticle5.com/review-history/117172