Journal of Basrah Researches (Sciences) **48**(2), 14 (2022)
DOI: https://doi.org/10.56714/bjrs.48.2.2

Use of full automated microfluidic technique for determination of Zinc (II) in pharmaceutical preparations with 8-Hydroxyquinoline

Ihsan A. Mkashaf[1*], Kamel H. Al-Sowdani[1], Abdulla J. Y. Aldarwish[2]

[1]Department of Chemistry, College of Education for Pure Science, University of Basrah, Basrah, Iraq.
[2]Department of Computer Science, College of Education for Pure Science, University of Basrah, Basrah, Iraq.

A R T I C L E I N F O

Received 02 January 2022
Accepted 28 February 2022
Published 30 December 2022

K e y w o r d s :

Full automated microfluidic homemade, Zinc(II) in pharmaceutical preparations, 8-Hydroxyquinoline reagent.

Citation: I.A. Mkashaf et al., J. Basrah Res. (Sci.) **48**(2), 14 (2022).
DOI:https://doi.org/10.56714/bjrs.48.2.2

A B S T R A C T

The full automated microfluidic system has been designed for the determination of zinc (II) ion in pharmaceutical samples home-made. Two-channel microchips (30 µl×4 cm) was designed in this study. The proposed system was controlled by using Arduino UNO and Mega microcontrollers. The first type was utilized to control the homemade micro-peristaltic pump to withdraw samples and chemical reagents in the microchip and then to the spectrophotometer equipment with 7-microliter flow cell. The other one type is Mega, was used as a data-logger to manipulate and recording the results as peak height corresponding the concentration by using Microsoft Excel 2016 program. The linearity was ranged 1-7 µg/ml, the correlation coefficient (R2) was 0.9998. The relative standard deviation for ten measurements of Zn(II) ion 4 µg/ml was (0.982%), as well as the detection limit was 0.125 µg/ml. The dilution factor of this system was 1.07.

1. Introduction

Microfluidics is defined as the science and technology of systems in which small quantities (10^{-9}-10^{-18} liters) of liquids are processed using microchips containing micro-channels with micro scales ranging from tens to hundreds of micrometers [1-3]. Microfluidics are widely used to reduce analytical processes because of their many advantages, such as consuming small quantities of samples and reagents and improving system performance by integrating several analytical processes into one tool, where detection and separation operations are carried out with accuracy and high sensitivity, in addition to short analysis time and low cost, as well as little production waste[4-7]. As a result of these good features, this technology has gained great interest in the fields of biology, chemistry, medicine, and engineering[8-10]. Microchip-based analysis systems are systems in which one or more chemical processes are carried out for the purpose of analysis using very small volumes of liquids, these applications are called Total Microanalysis Systems or chip-on-Lab technology (LOC) [11-13]. Zinc is essential for growth. It is also one of the elements involved in stimulating biological functions such as cellular integrity and protein synthesis [14–15]. Zinc plays an important role in brain development as well as an antioxidant [16]. Zinc is a popular nutritional supplement on its own or as part of a nutritional formula that contains vitamins,

*Corresponding author email : ihsan.mkashaf@uobasrah.edu.iq

ISSN: 1817-2695 (Print); 2411-524X (Online)
Online at: https://bjrs.uobasrah.edu.iq

minerals, and other nutrients [17]. Most zinc supplements are taken orally, either as a single or divided dose, in tablet or capsule form, or as concentrated syrup. Zinc can reduce the risk of contracting viral respiratory infections, including SARS-CoV-19, and shorten the duration and severity of illness [18–21]. A spectrophotometer can determine the presence of zinc as one of the most common elements in pharmaceutical preparations. There are several FIA methods that have been used for the determination of zinc (II) [22–25].

The aim of the research: Design of a homemade fully Automated Microfluidic System for the Determination of Zinc Dioxide in Pharmaceutical Preparations Using 8-Hydroxyquinoline Reagent.

2. Materials and Methods

Microfluidic system design

A home-made microfluidic system was designed for the determination of zinc (II) in pharmaceuticals. A two-channel micro slide was fabricated with dimensions of 30 μL x 4 cm, each channel containing a volume (15 μL) resulting in the use of very small reagent and sample volumes. The designed system is equipped with microcontrollers of the Arduino type, the first of the UNO type, that control the peristaltic pump, which in turn takes samples and reagents, and the other type of Mica works by receiving the analog signal from the detector and converting it into a digital signal and then sending it to the computer processor, which outputs it in the form of Tops in Microsoft Excel 2016 and locally designed.

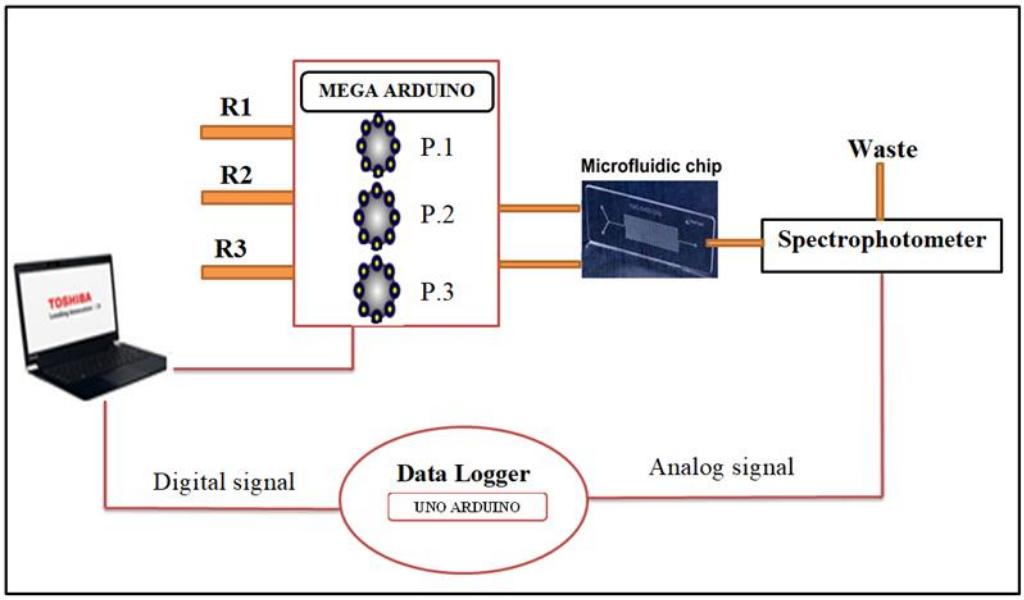
2.2 Preparation of solutions and reagents for the determination of zinc (II) in pharmaceutical preparations.

All the chemicals used are of high purity, and distilled water free of ions has been used.

1. The standard solution of zinc (II) was prepared from zinc (II) sulfate (aqueous ($ZnSO_4.7H_2O$) at a concentration of 100 ppm by dissolving (gram 0.4933) of the substance in 100 ml of deionized water, from which the standard solutions were prepared by the dilution method sequentially.
2. Preparation of sulfuric acid solution: A solution of sulfuric acid was prepared at a concentration of 0.1 M in a volumetric bottle (100 ml).
3. Preparation of ammonium hydroxide solution: ammonium hydroxide solution was prepared by taking 10 ml in a volumetric bottle of 100 ml capacity, then we completed the volume to the mark by adding distilled water free of ions.

3. Result and Discussion:

The locally designed microfluidic system Figure (1) was used for the determination of zinc (II) in pharmaceutical preparations under the optimal conditions studied and with a wavelength (380 nm) in Figure (2).



where R1 denotes the sample, R2 the reagent, and R3 the current carrier solution

Fig. 1 Microfluidic Apparatus for the Determination of Zinc (II) in Pharmaceutical Preparations

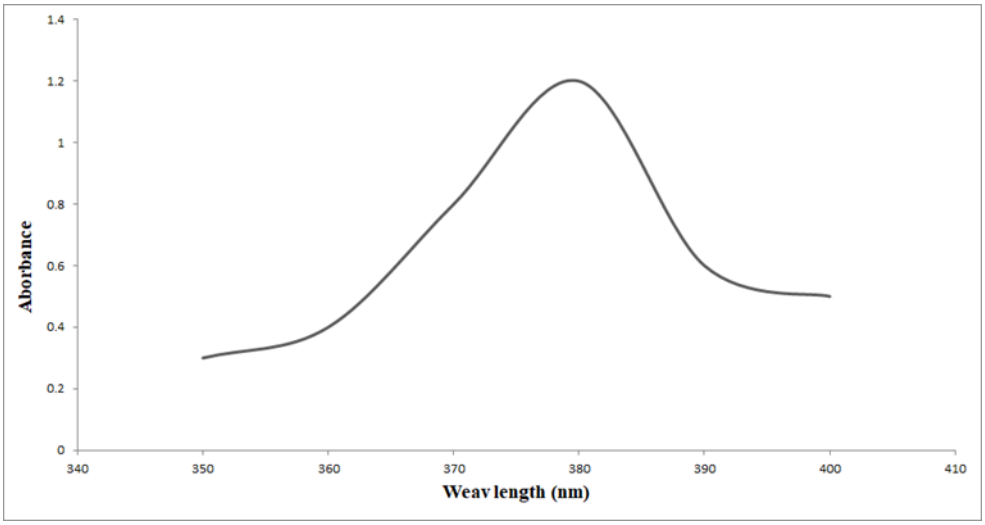


Fig. 2 The maximum wavelength of the Zn-8HQ complex

3.1 **Optimum Conditions for the Determination of Zinc (II) in Pharmaceuticals**.

3.1.1 The effect of the flow rate:

The effect of the flow rate within the range (0.5 -2.5 ml/min) on the peak height resulting from (4µg/mL) zinc (II) withdrawal was studied, as the increase in the flow velocity leads to a decrease in the peak height due to the formation of the resulting complex Figure (3) and table (1). Therefore, the choice of speed (1 ml/min) was chosen for the purpose of obtaining a short analysis time and a high modelling speed.

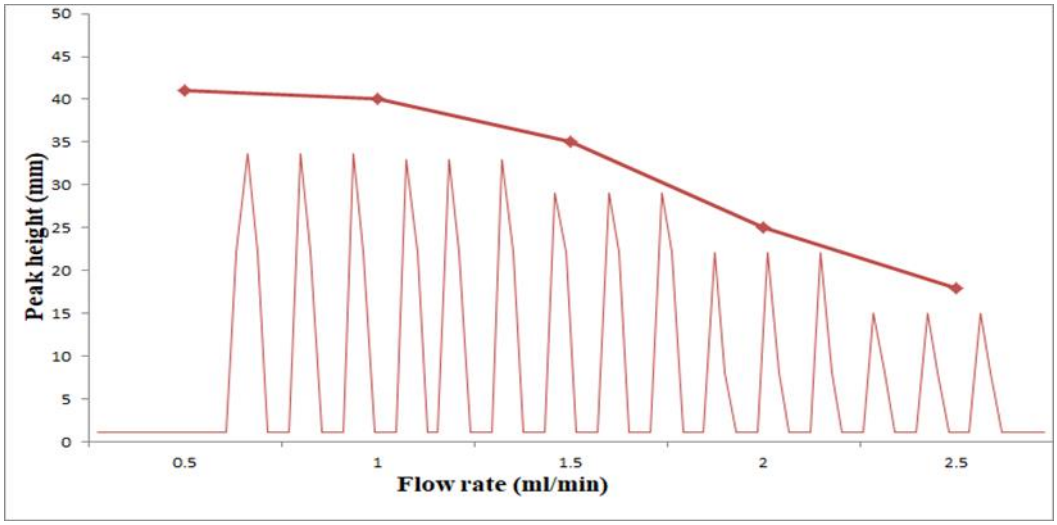


Fig. 3 Effect of flow Injection on peak height after zinc (II) withdrawal (4µg/mL)

Table 1 Effect of the flow Injection on the peak height resulting from the withdrawal of (µg/mL 4) of zinc (II).

Flow rate (ml/min)	peak height rate (mm)
0.5	41
1	40
1.5	35
2	25
2.5	18

3.1.2 Effect of slide slit length.

The height of the top formed by withdrawing (µg/mL 4) zinc (II) shows a noticeable increase in the height of the top when the incision of the slice is increased, and it quickly begins to decrease within the range (0.5-2.5 cm) due to the increase in the dilution when the length of the incision of the slice was increased. choosing 1.5 cm as the best incision length for subsequent studies Figure (4) and table (2) .

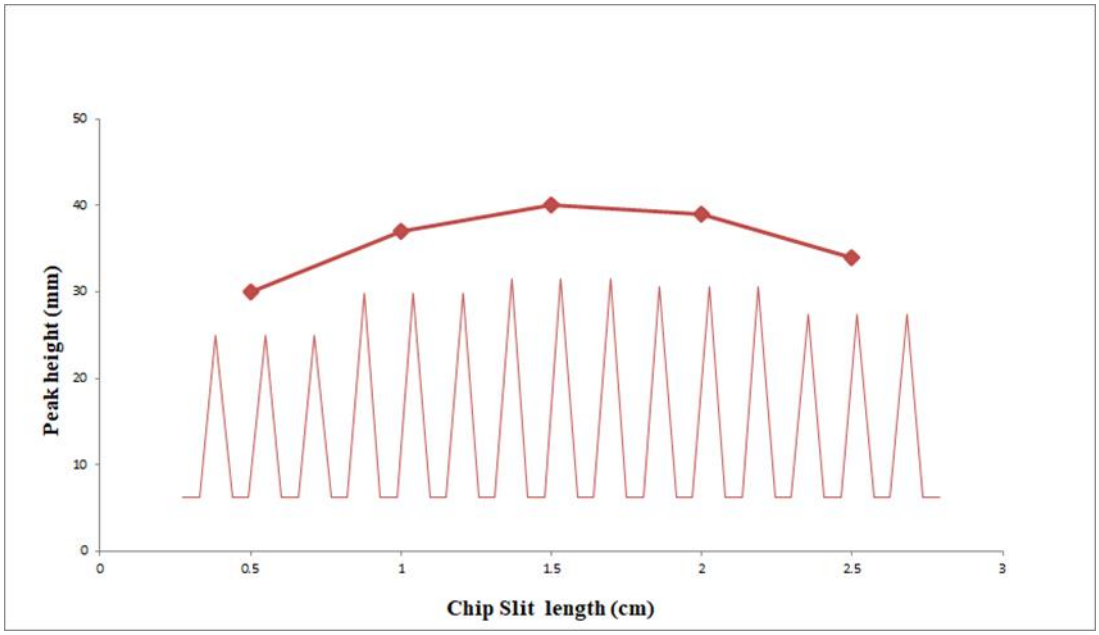


Fig. 4. Effect of the length of the chip slit on the height of the peak resulting from the withdrawal of (4 µg/mL) of zinc (II).

Table 2. The length of the incision of the slice at the height of the top results from the withdrawal of (4 µg/mL) of zinc (II).

slit length(cm)	peak height rate (mm)
0.5	30
1	37
1.5	40
2	39
2.5	34

3.1.3 The effect of sample volume:

An increase in the height of the top formed by clouds (4µg/mL) was observed when the sample volume was increased within the range (10–50 µL), which allowed the complex to form when the size of the model used was increased, as we chose the size (50 µL) of the model as the best size to study other conditions (Fig. Figure (5) and table (3) after stabilizing the velocity of (1 ml/min) and the length of the reaction slit (1.5 cm).

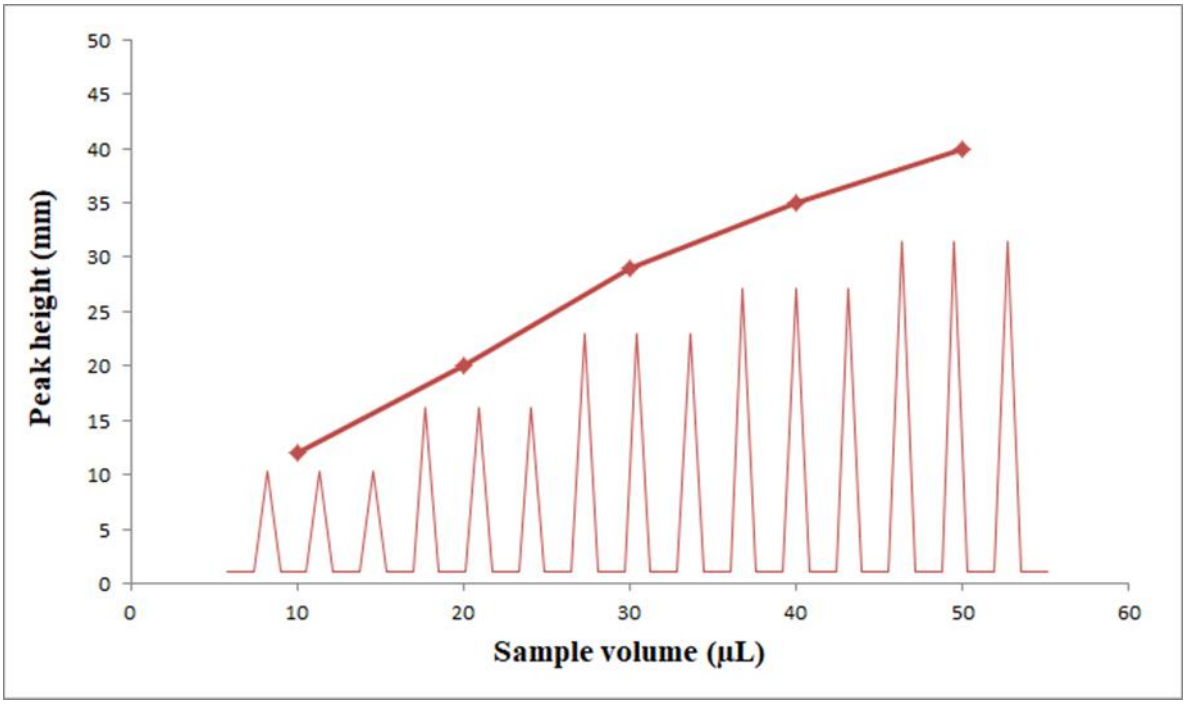


Fig. 5 Effect of the sample volume on the peak height resulting from the withdrawal of (4 µg/mL) of zinc (II).

Table 3 Effect of sample size on peak height resulting from withdrawal (4 µg/mL) of zinc (II).

Sample volume (µL)	peak height rate (mm)
10	12
20	20
30	29
40	35
50	40

3.1.3 Effect of 8-hydroxyquinoline reagent concentration:

The increase in the concentration of the 8-hydroxyquinoline reagent leads to an increase in the peak height resulting from the withdrawal of (4 µg/mL) zinc (II) after stabilizing the flow rate (1 ml/min), sample volume (50 µL) and the slide incision length (1.5 cm). The concentration (1.2 w/v%) was chosen for subsequent studies as soon as the peaks began to decline at high detector concentrations and within the range (0.1-1 w/v%) in order to consume the sample used and the availability of a quantity of the reagent Figure (6) and table (4).

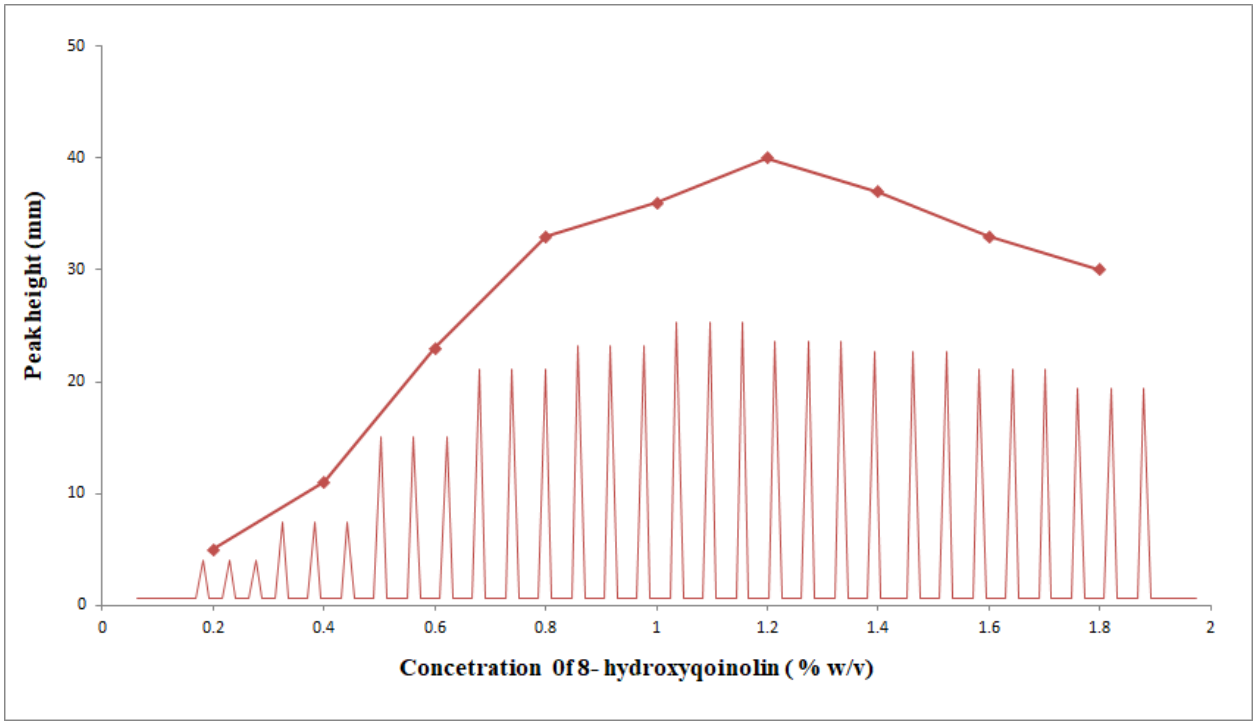


Fig. 6 Effect of 8-hydroxyquinoline concentration on peak elevation caused by zinc (II) withdrawal (4µg/mL).

Table 4 Effect of 8-hydroxyquinoline concentration on peak height resulting from withdrawal (4 µg/mL) of zinc (II)

peak height rate (mm)	Concentration w/v %
5	0.2
11	0.4
23	0.6
33	0.8
36	1
40	1.2
37	1.4
33	1.6
30	1.8

3.1.4 Effect of sulfuric acid volume:

The rise in the peak resulting from the withdrawal of (4µg/mL) of zinc (II) quickly suffers a decrease when the volume of sulfuric acid increases within the range (0.1–1 ml) due to the lack of absorption at high volumes of acid Figure (7) and table (5), as was chosen, (0.5 ml) as the best volume for the study after stabilizing other conditions of flow rate of 1 ml/min, sample volume of 50 µL, and slide incision length of 1.5 cm.

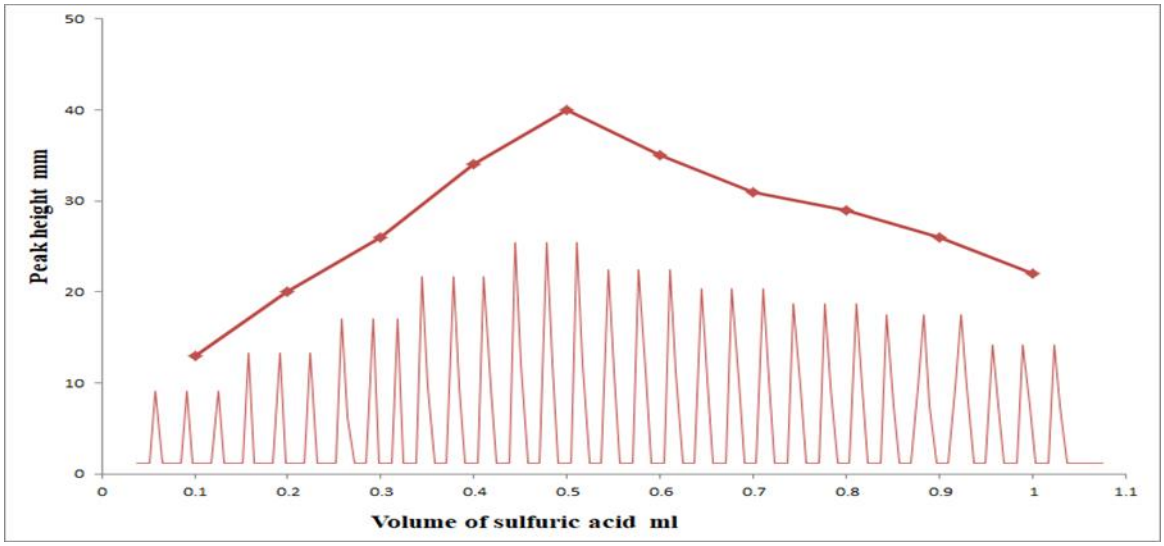


Fig. 7 Effect of the volume of sulfuric acid on the peak height resulting from the withdrawal of (µg/mL 4) of zinc (II).

Table 5. Effect of the volume of H2SO4 on the height of the peak resulting from the withdrawal of (µg/mL 4) of zinc (II).

peak height rate (mm)	Volume of sulfuric acid (ml)
13	0.1
20	0.2
26	0.3
34	0.4
40	0.5
35	0.6
31	0.7
29	0.8
26	0.9
22	1

Table 6. Optimal conditions for the determination of zinc (II) in pharmaceutical preparations.

The value	Factors
1	Flow rate ml\min
0.5	Acid volume ml
50	Sample volume µL
4	Slit chip length cm
0.7	10.1 phenanthroline concentration w/v%

3.2 The Standard Calibration Curve.

Under the optimum conditions that were obtained and as shown in Table (6) for the determination of zinc (II) ion in pharmaceutical preparations by the completely autologous microfluidic method, the standard calibration curve was studied as in Figure (8), and the linear relationship within the range (1- 7 µg/mL) was found for the peaks of concentrations shown in Table (7) and Figure (9.b). The correlation coefficient (R^2) for seven points was 0.9998, and the relative standard deviation (R.S.D%) for ten points was 0.982% in Figure (9.c), with a detection limit of0.125 µg/mL. The equation y = 9.8571x + 0.25 shows the relationship between the concentration and the peak height, where y represents the peak height and x represents the concentration of zinc (II).

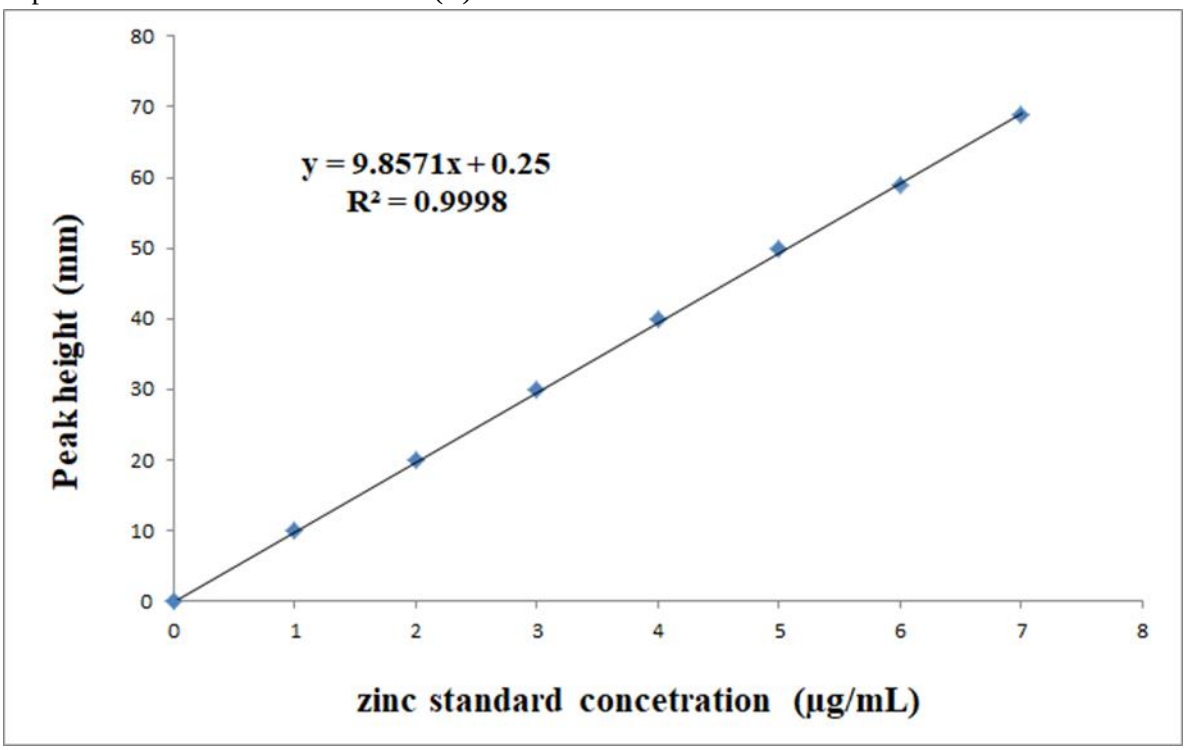


Fig. 8. calibration curve for microfluidic determination of zinc (II) ion in pharmaceutical preparations

Table 7. Peaks of the calibration curve.

peak height rate (mm)	Concentration (µg/mL)
10	1
20	2
30	3
40	4
50	5
59	6
69	7

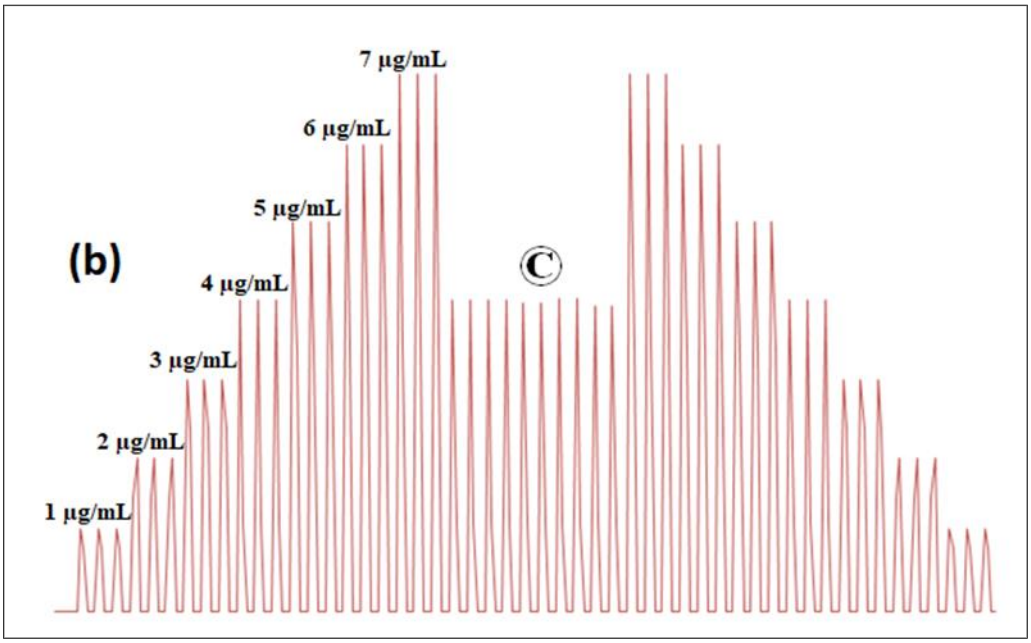


Fig. 9.

b. The resulting peaks of zinc (II) were withdrawn three times for each concentration.

c. The peaks resulting from the withdrawal of 4 µg/L zinc(II) times

3.3 Dispersion: The dilution factor of the manifold unit of the designed system was 1.07 in Figure (10).

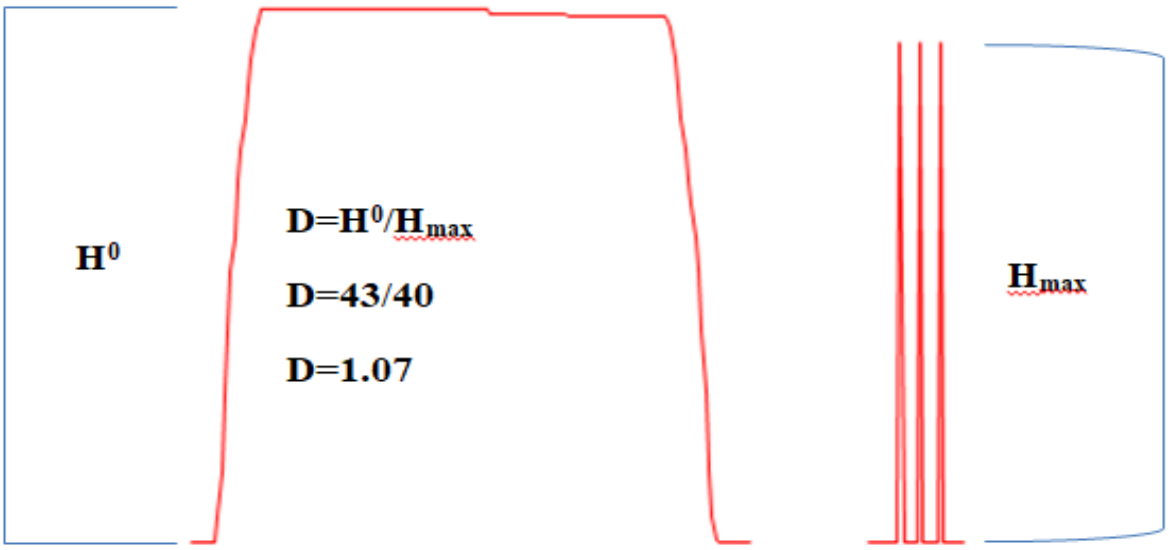


Fig. 10. Dispersion Factor for Zinc (II) Ion Determination System.

3.4 **Analytical applications**.

We used the microfluidic system designed for the determination of zinc (II) ion for four samples taken on-site from pharmacies in Basrah governorate within the range of 1–7 g/mL Table (8).

Table 8. Concentrations of Zinc (II) in Selected Pharmaceutical Preparations.

Sample	Zinc added (µg/mL)	Total zinc (µg/mL)	Total zinc found (µg/mL)	Recovery %
Tablet 2	4	0.2567	0.2459	97.96
Tablet3	4	1.0389	1.0400	98.01
Capsule4	4	0.1366	0.1359	96.98

3.5 Interferences.

Table (9) shows the peak height resulting from the withdrawal of 0.8 µg/mL of Zinc (II)in the presence of (1,10, 100, 1000 µg/ml) of positive and negative ions, NO_3^-, $SO4^{-2}$, Ca^{+2}, Mn^{+2} Cu, Ni $^{+2}$, Co $^{+2}$ Sn, Cd, Ca, Ba. It was observed that the majority of ions had no effect on the determination of zinc (II) in pharmaceutical preparations through stability in the height of the peak.

Table 9. Interferences Effect

Foreign cation (+2)	Peak height mm			
	Folds			
	1	10	100	1000
Ba	50	47	42	36
Co	51	46	40	34
Cu	44	39	32	26
Ni	47	41	34	29
Cd	52	44	38	31
Ca	56	53	50	41
Pb	51	50	51	48
Mn	54	54	53	52
Sn	55	54	52	51

4. Conclusions.

- Homemade and designing a completely self-contained microfluidic system for the first time in our university laboratories by using microfluidic chips for the determination of zinc binary ions in pharmaceutical preparations.
- Manufacture of micro-pumps from materials available in the local market, which were characterized by different speeds that were controlled by Arduino microcontrollers.
- Processing the data represented by the analog signal and converting it into digital signals that are easy to process using the Mega controller and drawing it on the Excel 2016 program.
- The possibility of using very small volumes made the designed system friendly to the environment in terms of waste disposal, consisting of the use of models and reagents

5. References

[1] N. Hao, Y. Nie, A. Tadimety, T. Shen, J.X. Zhang, Biomater. Sci. **6**(12), 3121 (2018).

[2] A.G. Niculescu, C. Chircov, A.C. Bîrcă, A.M. Grumezescu, International Journal of Molecular Sciences **22**(4), 2011 (2021)

[3] H. Tavakoli, W. Zhou, L. Ma, S. Perez, A. Ibarra, F Xu, S. Zhan, X. Li, TrAC Trends in Analytical Chemistry **117**, 13 (2019).

[4] H. Tewr, W. Zarea, S. Zhan, TrAC Trends in Analytical Chemistry **117**, 13 (2019).

[5] J. Sengupta, C.M. Hussain, Trends in Analytical Chemistry **114**, 326 (2019).

[6] L.Y. Yeo, H.C. Chang, P.P. Chan, J.R.J. Friend, small **7**(1), 12 (2011).

[7] M.Hunt, M. Taverne,J. Askey, A. May, A.V. Berg,Y.D. Ho,J. Rarity, S. Ladak, Materials **13**(3), 761 (2020).

[8] B.K. Gale, A.R. Jafek, C.J. Lambert, B.L. Goenner, H. Moghimifam, U.C. Nze, S.K. Kamarapu, Inventions **3**(3), 60 (2018).

[9] M.J. Begemann, B.A. Brand, B. Ćurčić-Blake, A. Aleman, I.E. Sommer, Psychological medicine **50**(15), 2465 (2020).

[10] Y.S. Al-Jorani, K.H. Al-Sowdani, Materials Science and Engineering **871**, 012032 (2020).

[11] I.A. Al-Asady, K.H. Al-Sowdani, Journal of Physics **2063**, 012018 (2021).

[12] M. Islam, R. Natu, R. Martinez, Microfluidics and Nanofluidics **19**, 973 (2015).

[13] M.J. Begemann, B.A. Brand, B. Ćurčić-Blake, A. Aleman, I.E. Sommer, Psychological medicine **50**(15), 2465 (2020).

[14] F.Z. Es-sbihi, Z. Hazzoumi, A. Aasfar, K.J. Amrani Joutei, Chem. Biol. Technol. Agric. **8**(1), 1 (2021).

[15] K. Grüngreiff, T. Gottstein, D.J.N. Reinhold, Nutrients **12**(11), 3548 (2020).

[16] L.E. Blanc, D. Kundu, L.F.J. Nazar, Joule **4**(4), 771 (2020).

[17] A.M. Uwitonze, N. Ojeh, J. Murererehe, A. Atfi, M.S.J. Razzaque, Nutrients **12**(4), 949 (2020).

[18] S. Read, S. Obeid, C. Ahlenstiel, G. Ahlenstiel, Advance Nutrition **10**, 696 (2019).

[19] K. Grüngreiff, T. Gottstein, D.J. Reinhold, Nutrients **12**(11), 3548 (2020).

[20] A.M. Uwitonze, N. Ojeh, J. Murererehe, A. Atfi, M.S.J. Razzaque, Nutrients **12**(4), 949 (2020).

[21] S.A. Read, S. Obeid, C. Ahlenstiel, G.J. Ahlenstiel, Advances in nutrition **10**(4), 696 (2019).

[22] J.S. Becker, N.J.C.S.R. Jakubowski, Chemical Society Reviews **38**(7), 1969 (2009).

[23] N.S.T. Al-Awadie, M.K.K. Al-saeedi, IJRPC **6**(4), 650 (2016).

[24] C.E. Säbel, J.M. Neureuther, S.J. Siemann, Analytical biochemistry **397**(2), 218 (2010).

[25] R.N. Páscoa, I.V.TothS, A.O. Rangel, Talanta **84**(5), 1267 (2011).

Journal of Basrah Researches (Sciences) **48**(2), 14 (2022)
DOI: https://doi.org/10.56714 /bjrs.48.2.2

أستخدام تقنية المايكروفلودك الذاتية كليا لتقدير الزنك (II) في المستحضرات الصيدلانية مع 8- هيدروكسي كوينولين

إحسان عاشور مكشف*[1] ، كامل حسين السوداني[1] ، عبد الله جاسم ياسين الدرويش[2]

[1]قسم الكيمياء، كلية التربية للعلوم الصرفة، جامعة البصرة، البصرة، العراق.

[2]قسم علوم الحاسوب، كلية التربية للعلوم الصرفة، جامعة البصرة، البصرة، العراق.

معلومات البحث

الاستلام 2 كانون الثاني 2022
القبول 28 شباط 2022
النشر 30 كانون الاول 2022

الكلمات المفتاحية

نظام مايكروفلودك محلي الصنع، الزنك الثنائي في المستحضرات الصيدلانية، كاشف 8-هيدروكسي كوينولين

Citation: I.A. Mkashaf et al., J. Basrah Res. (Sci.) **48**(2), 14 (2022).
DOI:https://doi.org/10.56714/bjrs.48.2.2

الملخص

تم تصميم نظام مايكروفلودك ذاتي كليا لتقدير الزنك (II) في المستحضرات الصيدلانية محليا في مختبراتنا. تم تصميم شرائح مايكروية ثنائية القناة (30 µL×4 cm). تم التحكم بالنظام المصمم بإستخدام متحكمات دقيقة (الأردوينو) من نوع UNOو Mega. إن النوع الأول تم إستخدامه للتحكم بالمضخة التمعجية المايكروية لسحب العينات والكواشف الكيميائية الى الشريحة المايكروية ثم الى مقياس الطيف الضوئي والمجهز بخلية جريان عابر (Flow cell) وبحجم 7 µL ،أما النوع الاخركان من نوع Mega يعمل على تحويل الاشارة التماثلية المستلمة من المكشاف وتحويلها الى إشارة رقمية وبالتالي أرسالها الى معالج الكمبيوتر ليتم تسجيلها على شكل قمم ببرنامج الاكسل 2016 والذي تم تصميمه محليا. وجدت العلاقة الخطية Linearity ضمن المدى µg/mL 1-7. وجد إن معامل الارتباط 0.9998 Regression coefficient وإن الأنحراف القياسي النسبي Relative standard deviation (R.S.D%) لعشر قراءات متتالية من 4 µg/mL الزنك (II) يساوي 0.982% وحد الكشف 0.125 µg/mL ، وإن معامل التخفيف للنظام المصمم 1.07.

*Corresponding author email : ihsan.mkashaf@uobasrah.edu.iq

ISSN: 1817-2695 (Print); 2411-524X (Online)
Online at: https://bjrs.uobasrah.edu.iq