



Mass-time equivalence in dynamic equilibrium systems

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Received: 20 November 2023 / Accepted: 25 December 2023 / Published online: 10 February 2024
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Abstract

The truth of time has been debated for more than two centuries. Scientists like Leibniz, Einstein, Rowley, Wheeler and DeWitt believe that it is the result of change in the world and is not original. According to our research, only Einstein introduced the law of space–time and showed that time is woven in space (general relativity), but no one (at least in classical physics) explained the relationship between time and changes in the world (mass and energy). In the rest of the references, only mathematical and theoretical topics are presented. In kinetic experiments (in various scientific fields), time is used as a variable to plot kinetic curves. This choice is neither scientific nor based on principled modeling. For this reason, kinetic models are presented experimentally. The aim of this research is (1) to introduce the "dynamic mass ($\partial M_{out}/\partial M_{in}$)" equation as a platform for mass-based modeling in open systems. (2) Introducing the relationship between mass (m) and time (t) or mass-time equivalence in mass flows (mass conversion or mass transfer system). (3) Expansion of time relativity in mass-mass systems. To achieve the objectives of the study, the equation "dynamic mass ($\partial M/\partial M$)" based on the law of conservation of mass has been introduced for the first time. Then, using the dynamic mass equation, the absorption model was presented in two mass forms (mass-mass curve) and time (mass-time curve). Then, using Fe^{2+} , Pb^{2+} , Cr^{6+} , Ni^{2+} , Cd^{2+} and As^{2+} elements and Jacobi activated carbon, Iranian activated carbon, and blowy sand adsorbents, routine kinetic and isotherm tests were performed separately. To evaluate the absorption model, three methods were used: (1) evaluation by evaluation indices (R^2 and RMSE) and (2) comparison of the "temporal form of the model" with the kinetic models of absorption (Lagergren and Ho et al.) and (3) comparison of the "mass form of the model" with Shammahmadi adsorption isotherm model.

Keywords Adsorption kinetic model · Dynamic mass equation · Adsorbent capacity · Mass-time equivalence

Introduction

Time as a tool plays an important role in understanding mass processes. Also, time plays an important role in daily, monthly and yearly planning. Many models in water (Zehe et al. 2001; Mein and Larson 1973; Shamohammadi, et al. 2023a), soil (Philip 1957b; Argyrokastritis and Kerkides 2003; Ghorbani et al. 2009; Shamohammadi et al. 2023b) and chem, Pseudo first order, Pseudo second order Elovich model, Bhattacharya and Venkobachar, Natarajan and

Khalaf and Intra-particle diffusion (Srihari and Ashutosh 2008; Shamohammadi et al. 2013). It is written based on time, which are known as kinetic models (mass-time relationship).

But the issue that few people explain about is that in all mass processes (regardless of whether the process is called kinetic or not), one mass turns into one or more other masses (Shamohammadi 2016; William et al. 2012 Shamohammadi et al. 2023a). As a result, for modeling, the input (M_{in}) should always appear as an independent variable and the output masses (M_{out}) as function variables in the model (William et al. 2012). But the study, based on an accepted procedure in kinetic experiments, considers time as an independent variable. In fact, time is used instead of the independent variable (M_{in}). In other words, in System of coordinates, "t" are shown in the horizontal axis and M_{out} in the vertical axis (Zehe et al. 2001; Mein and Larson 1973; Philip 1957b; Argyrokastritis and Kerkides 2003). It is true that the change of mass is measured with time, and time can be used as an independent variable instead of the input mass,

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but in the process of converting mass, it is not a constant mass, while the passage of time is constant. Hard to fix this defect, based on their experience in the initial experiment, Δt is considered small and gradually large so that the "reaction time" matches the mass rate of the reaction. In any case, their goal is to be placed in the horizontal axis ($M_{in} = t$) when drawing the curve (Shamohamadi et al. 2023b).

The reason for accepting this rule may lie in the definition of time unit. as we know. the unit of time is defined by the International System of Units based on the electromagnetic wave emitted by a cesium 133 atom (As a result of electron transfer from excited state to ground state at zero Kelvin temperature), so that if the electromagnetic wavelength is Denote by λ , the duration of each second is equal to $9,192,631,770 \lambda$ (Verma and Bose 2017). In other words, in the definition of time unit, time has no originality, but time takes its validity from wavelength (mass and energy). Therefore, using time instead of mass in kinetic models is not far from the mind, but it seems that this rule can be expressed better.

This issue can also be found in the comments of great scientists. Since the late nineteenth century, physicists and mathematicians have questioned absolute time, and Leibniz was the first to believe that time does not exist independently. He argued "that time must be the result of change" and without change in the universe, there can be no time. Einstein (Einstein 1905; Aljeboree et al. 2017; Alcocer 2020) showed in the theory of general relativity that Speed slows down time. Also, as gravity increases, the clock hand spins more slowly and thus time slows down. In fact, he showed that past and future do not exist and time is "a sequence of events that are happening". Based on the space–time model, it can be concluded that an event is both space and time. So events can be represented by a specific point in space–time. In other words, time is not a reality apart from physical phenomena. "Wheeler" and "DeWitt" (Alley 1979; Verma and Bose 2017) in the "fundamental equation of quantum cosmology" which became known as the Wheeler-DeWitt equation, showed that there is no "time" in the quantum world. In other words, "the universe can be explained without time". Also, according to Rovelli (Shamohammadi et al 2023b), what is observed in reality, physical variables are interdependent and occur in sequence, but we display it as if everything is changing over time. In other words, there is no time, but "the change of variables as if there was time". He believes that "the truth of the world lacks the passage of time, but it is our incomplete understanding of this truth that forms the concept of time. Therefore, time is formed from our ignorance". Barbour describes time by likening the whole world to the frames of a motion picture: successive images, successive snapshots, which continuously change into each other (Sidharth and Das 2018).

In classical physics (in the field of mass), one of the basic and important laws is the law of conservation of mass. Therefore, any model that is not written based on the law of conservation of mass is obtained through empirical methods. One of the disadvantages of kinetic modeling is that mass-mass process curves are written as mass-time. For this reason, the law of conservation of mass cannot be used in building a kinetic model (Srihari and Ashutosh 2008; Shamohamadi et al. 2013).

Shamohamadi (2023b) first used the law of conservation of mass to construct a kinetic model. In the tests of water penetration into the soil, he considered the amount of water entering the soil (H) as an independent variable, and the amount of water that penetrated the soil (I) and the amount of water remaining on the soil surface (h) as variables. Function considered. Then, by using the law of conservation of mass, he built the penetration model as mass-mass. In the end, he used the time parameter instead of the independent variable (H) and presented the penetration kinetics model.

There is no closed system in nature. For example, gravity cannot be eliminated in any system (Smolin 2014), but for the simplicity of calculations in modeling, we always assume that the process system is closed. In addition to causing errors in modeling, the assumption of "closed system" also causes limitations in modeling. Langmuir used a closed system to build an adsorption isotherm model, which led to the equality of the forward and reverse speeds. This gross mistake made him unable to obtain chemisorption, which was his main goal, because his model led to an equilibrium model with the independent variable C_e (residual concentration), while C_e is not an independent variable (Shamohamadi et al. 2022; Shamohammadi 2016).

In this research, using absorption experiments (creating mass flow in both chemical and physical absorption), we showed that if the law of conservation of mass (in the form of dynamic mass equation) is used, it can be proved: (1) Description of processes requires They do not have time and are easily explained by mass-mass equations. (2) Time parameter (t) can be used instead of the independent variable of input mass (M_{in}). (3) It can be modeled in open systems that are compatible with natural behaviors, and there is no need to limit the system to make a model.

The purpose of this research is (1) to introduce the "dynamic mass ($\partial M_{out}/\partial M_{in}$)" equation as a platform for mass-based modeling in open systems. (2) Introducing the relationship between mass (m) and time (t) or mass-time equivalence in mass flows (mass conversion or mass transfer system). (3) Expansion of time relativity in mass-mass systems.

The use of "mass-time equivalence" in adsorption studies makes (1) adsorption isotherm equations and adsorption kinetic equations to be written in the same form, and there is

no need for different Equations. (2) Elimination of isotherm tests, as a result, all the goals of kinetic and absorption isotherm models can be achieved with the least number of tests, while saving money. (3) Accuracy is increased in modeling.

According to our studies, no study has been done on the relationship between mass and time. Also, no study has been found to show that adsorption kinetic models are able to calculate the maximum adsorption capacity. As a result, (1) introduction of dynamic mass equation, (2) law of mass-time equivalence, (3) presentation of absorption kinetics model that is able to calculate the capacity of the absorber is one of the innovations of this research. Also, time relativity in mass-mass systems is considered a new theory.

An introduction to the model

Definitions and concepts

Dynamic mass: In a "mass conversion process (with or without change in nature), the materials participating in that process are called dynamic(variable) mass.

For example, in the chemical reaction of converting N_2O_4 to $2NO_2$ (whether the equilibrium is complete or not), both substances are called dynamic mass. In converting precipitation (p) to runoff (Q) and retention (S), all three parameters p , Q and S are dynamic (Shamohammadi et al. 2023a). This issue in surface absorption, when C_0 (initial concentration) is converted to q (amount of material absorbed to the adsorbent surface) and C_e (equilibrium concentration), we call all three dynamic mass parameters (Shamohammadi et al. 2023b). Dynamic mass is generally denoted as M , dM or ∂M .

Dynamic mass equation: In a mass process (open system), the total mass rate of the components is equal to unity. For example, in a open system, when the mass M (independent variable) is converted into components m_1 , m_2 and m_3 , the dynamic mass equation is obtained as (Eq. 1). What we mean by open system is that the input mass and the output mass are seen separately. Obviously, the interaction system is completely isolated.

Attention: In the definitions and equations above, the speed (v) of mass transfer (from one point to another point) is considered to be zero, so the kinetic energy of the carrier is zero. In other words: $v = 0 \rightarrow \frac{1}{2}mv^2 = 0$

In a mass flow (open system), the law of conservation of mass can be written as the equation $\partial M_{in} = \partial M_{out}$. For example, if we assume that one substance turns into three other substances, the law of conservation of mass is written as $\partial M_{in} = \partial m_1 + \partial m_2 + \partial m_3$. Therefore, considering that in a mass flow, the input mass changes are not zero, by dividing the sides of the equation, we can always write: $\frac{\partial M_{in}}{\partial M_{in}} = \frac{\partial m_1}{\partial M_{in}} + \frac{\partial m_2}{\partial M_{in}} + \frac{\partial m_3}{\partial M_{in}}$
 n simpler terms, Dynamic mass equation can be written as Eq. 1:

$$1 = \frac{\partial m_1}{\partial M_{in}} + \frac{\partial m_2}{\partial M_{in}} + \frac{\partial m_3}{\partial M_{in}} \tag{1}$$

Dynamic mass Eq. (1) and Fig. 1 are the basis of modeling in a open system (with input mass M_{in} and output mass M_{out}).

Initial concentration (C): It is a part of the initial concentration that gradually participates in the reaction process. The value of C is always changing(Karimi 2013).

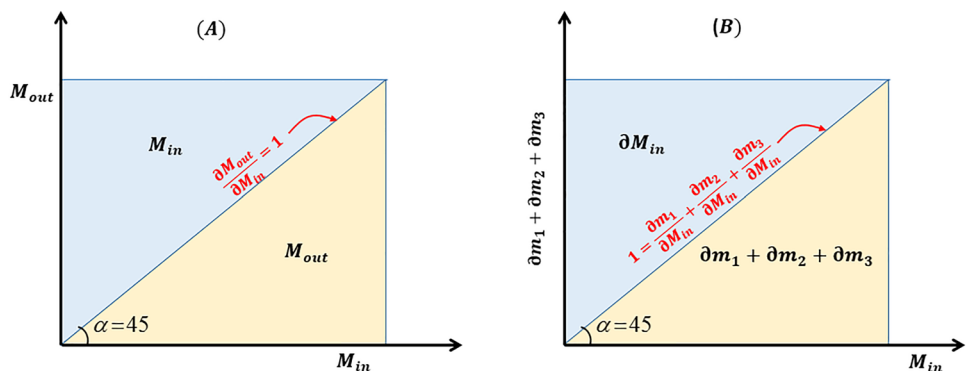
Equilibrium concentration (C_e): It is a part of the initial concentration that is desorbed and remains in the absorption system (for example, Erlenmeyer) (Aseel et al. 2017).

Physical absorption (q_e): It is a part of the initial concentration that is absorbed by the surface of the adsorbent in equilibrium conditions, it is called q_e. q_e is also called equilibrium absorption (Aseel et al. 2017).

Chemical absorption (q_{chm}): a part of the initial concentration that is absorbed by the surface during a chemical reaction (one-way or irreversible), is called chemical absorption. We also call chemical absorption capacity(shamohammadi et al. 2022; Shamohammadi 2016).

shamohammadi et al. (2023a) and William et al. (2012) showed that in the runoff precipitation curve, before the watershed system is balanced, the rain is retained one-way

Fig. 1 Law of conservation of mass for A (a linear relationship between input mass and output mass B) linear relationship between input mass and multiple output masses in a mass process system (Eq. 1)



(one-way reaction). Also, Shamohammadi et al. (2023b) showed that in the penetration of water into the soil, before the balance in the water and soil system, the water (one-way) is absorbed unilaterally by the soil.

Adsorbent capacity q_{max} : Adsorbent capacity is the maximum amount of material absorption by the adsorbent under ideal conditions(Langmuir 1916).

Total absorption (q): is the part of the initial concentration that has been absorbed by the adsorbent surface. The relationship between total absorption (solid phase concentration) and physical absorption (q_e) and chemical absorption (q_{chm}) is as $q = q_{chm} + q_e$ and $q_{max} = q_{chm} + q_{emax}$ (Shamohammadi et al. 2022).

Threshold of Dynamic Equilibrium (TDE): The boundary between the capacity of chemical absorption and physical absorption (equilibrium absorption) is called the threshold of dynamic equilibrium. At the threshold of dynamic equilibrium, the equilibrium concentration is zero. In mathematical terms: $\lim_{C_c \rightarrow 0} q = q_{chm}$ and $\lim_{C_c \rightarrow 0} C = C_{chm}$ in this case threshold point is introduced as TDE(C_{chm}, q_{chm}).

Law Mass-time equivalence ($m \equiv t$): In modeling based on the dynamic mass equation, time (t) can always be used instead of mass (m).

To achieve the results of "mass-time equivalence", the dynamic mass equation and Geometric representation of the dynamic mass equation can be used.

It was already mentioned that: Currently, in kinetic experiments (as an accepted procedure), the time parameter is used to explain the process of converting a mass (such as A) into a mass (such as B) in time. In other words, the time parameter is used in parallel with the "gradual transformation of A to B" and finally, instead of drawing the A-B model, the t-B model is drawn. Simply put, mass-time equivalence is done right now.

Therefore, we do not present a new issue, but we carry out the displacement of the parameter t and the mass

A(Min) through model building(and methodical), so that (1) the results of this displacement are more scientifically expressed, (2) the concept of mass-time equivalence is further developed. find.

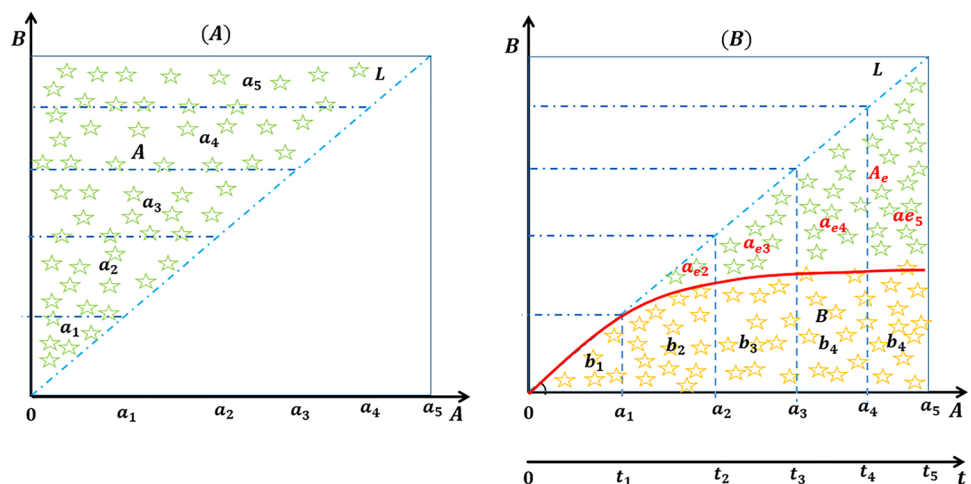
See Fig. 2 for more details. Suppose that material A is transformed into material B during an equilibrium process. In this case, according to the law of conservation of mass, the return material (Ae) can also be considered as an output material. (in surface absorption system $A = C, B = q$ and $Ae = Ce$).

As can be seen, in the equilibrium process, substance A gradually (a_1, a_2, a_3, \dots) turns into substance B + Ae ($b_1, b_1 + ae_1, b_2 + ae_2 \dots$), but in the laboratory instead of a_1, t_1 is written and instead of a_2, t_2 and so with this "instantaneous" displacement, the kinetic model is obtained as mass-time, that is: ($B = f(t)$).

In this study, contrary to the existing procedure, we do not replace t with A before building the model, but first obtain the mass-mass model by using the law of conservation of mass, then after extracting the model, instead of the variable A from We use the variable t. In this case, there are differences, some of which can be mentioned:

- (1) In the previous method, since the horizon axis is based on time, the law of conservation of mass cannot be used, as a result, it is not possible to draw the line L and determine the boundary of the input mass and the output mass, while in the new method, By drawing the L line, the amount of input and output materials can be determined and the amount of return material (Ae) can be easily calculated (in balanced systems).
- (2) In the previous method, choosing the value of t is not necessarily equal to the value of the converted substance (for example, we cannot be sure that at time t1 the value of a1 will be converted to b1), but in the new method, since the model is obtained without the intervention of t, we know that for each value of a, the values of b and ae are obtained (based on the law of conservation of mass).
- (3) The new method makes us realize that the mass-mass

Fig. 2 When in the kinetic experiment, time (t_1, t_2, t_3, \dots) is used instead of the independent variable A(a_1, a_2, a_3, \dots). **A** The input mass value (A) before conversion. **B** The output mass values ($B + A_e$) after conversion



and mass-time models are completely the same, only with a simple shift $t=A$, the kinetic model can be obtained. This is very important to save time and test costs.

In fact, in the new method, first the mass-mass model is obtained, then the time-mass model (kinetic), that is: $B=f(A)$, After that, by changing the variable t instead of A (equivalence law), we conclude that: $B=f(t)$.

An important result that can be obtained from the combination of dynamic mass equation and mass-time equivalence is that: the law of conservation of mass can always be used for modeling in open systems ($\partial M/\partial t=1$) and we do not have to Use the unrealistic assumption (closed system) and the law of conservation of mass in a closed system ($\partial M/\partial t=0$). It is obvious that $\partial M/\partial t$ represents the mass flow rate, so its unit can be expressed as grams per hour or grams per minute or other units.

Assumptions of model

1. In a solution containing an adsorbed substance and an adsorbent (homogeneous surface), the adsorbed are absorbed in several layers.
2. The first layer (q_{chem}) is formed by chemical reaction (one-sided reaction). At this stage, conditions are not created ($c_e=0$). (Shamohammadi et al. 2022).
3. The next layers of absorption are made by van der Waals force, which is absorbed by this type of absorption.
4. In the absorption stage, with the increase of primary solution materials, a part of the absorption components (q_e) and a part remain in the solution (C_e) to maintain balance, so that between the three points of "initial concentration", "equilibrium concentration" in the liquid phase (concentration)" and "compared with the solid phase (q_e)".
5. With the initial increase and the continuation of the new balance, the amount of absorption can increase in the end of the absorption capacity. As a result, the adsorbent

will no longer be able to absorb more (final balance) (Fig. 3).

In an absorption system, based on the law of conservation of mass, you can always write the mass relationship (Eq. 2) between the initial concentration of the reaction (C) and its components in a system (Erlen Meyer).

$$C = C_e + q \tag{2}$$

Therefore, based on the dynamic mass equation (derivation from both sides of the equation), we can write:

$$1 = \frac{dC_e}{dC} + \frac{dq}{dC} \tag{3}$$

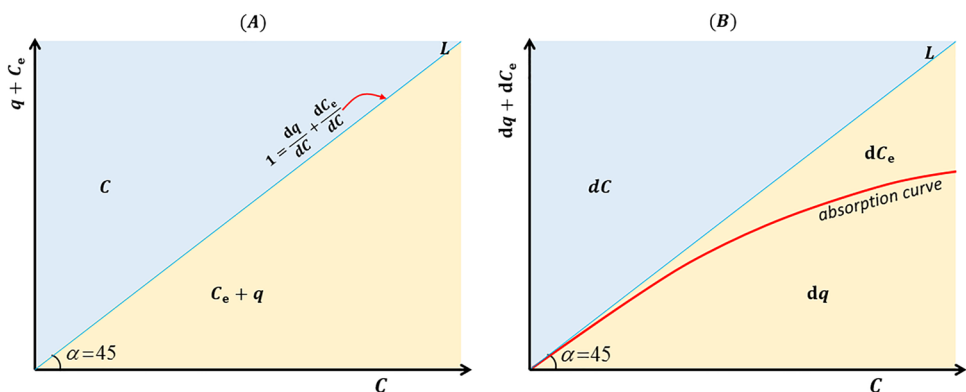
The parameters are already defined. Here, the unit of all parameters is in milligrams per liter (if the amount of adsorbent mass is determined, the unit of q can also be expressed in milligrams per gram).

According to Fig. 1. and the above definitions and assumptions, the absorption conceptual curve can be displayed as Fig. 3B. (Williams et al. 2012).

Models such as rainfall-runoff model (Williams et al. 2012; Shamohammadi et al. 2023a.), absorption isotherm model (Shamohammadi et al. 2022) and water infiltration models (Philip 1957b; Argyrokastritis and Kerkides 2003) show that there is a linear mass flow prior to formation. This issue has been confirmed in chemistry studies by Karimi (2013) and Shammohammadi et al. (2022). Shammohammadi et al. (2022) called the linear absorption of elements (one-way reaction) before creating equilibrium, chemical absorption and named it as a chemical principle. Figure 3 shows the law of conservation of mass (3-A) a and how to divide the initial concentration of the reaction into its components (3B) into absorbed substances (dq) and equilibrium concentration (dC_e).

Therefore, according to the conceptual curve (Fig. 3B), the assumptions of the model can be adjusted in the form of mathematical relations (4) and (7).

Fig. 3 Absorption conceptual curve **A:** Law of conservation of mass. **B:** How to divide the initial concentration of the reaction into its components (Shamohammadi 2016)



$$\frac{dC_e}{dC} = \frac{q}{q_{max}} \tag{4}$$

$$\frac{dq}{dC} = \frac{K_{sh}}{K_{sh} + C} \tag{5}$$

The K_{sh} parameter is the Model constant, which is a sign of the physical absorption capacity.

Reminder: because the angle between the line L and the horizontal axis (C) is 45 degrees, it is proved that for each value of x : $\frac{dx}{dL} = \frac{dx}{dC}$

By placing assumptions 4 and 5 in Eq. 6, and shifting the parameters, model (7) is obtained.

$$1 = \frac{q}{q_{max}} + \frac{K_{sh}}{K_{sh} + C} \tag{6}$$

$$q = q_{max} \frac{C}{K_{sh} + C} \tag{7}$$

Popescu (2022) showed that the adsorption kinetic curves and adsorption isotherm curves are completely similar. However, in the adsorption kinetic experiments, all the test parameters are constant and only time changes. While in the absorption isotherm tests, all the test parameters are constant and only the concentration (mass) parameter changes. Also, Shamohammadi presented the infiltration model by changing the variable "t" instead of "H" to build the infiltration model of "water in the soil" (Shamohammadi et al. 2023b).

Therefore, according to the dynamic mass equation and the results of studies by Shamohammadi et al (2023b), we change Figs. 3B, 4 and examine its results. In other words, is equivalent to $C(t \equiv C)$. In fact, we assume that in order to obtain the kinetic equation, the changes in time correspond

to the changes in C (this assumption is currently carried out in many kinetic studies). With this assumption, Eq. 7 becomes Eqs. 8 and 10 becomes Eq. 11, with the difference that q in hypothesis 4 and K_{sh} in hypothesis 5 become q_t and K_t respectively (these changes can be seen according to Fig. 4 review).

As mentioned before, because the unit of time relies on the wavelength of the cesium atom and has no origin of its own, it is not possible to define a specific mathematical relationship with a specific dimension, and the relationship $C=t$, does not mean that the unit of both sides of the equation is one, but it represents the temporal definition of mass changes. Just like when said: $L \equiv t$ Or should I say $9,192,631,770 \cdot \lambda = 1s$.

$$q_t = q_{max} \frac{t}{t_k + t} \tag{8}$$

As can be seen in model (8), the absorbing capacity is provided when the time tends to infinity, but less times are used to introduce the equilibrium time depending on the need (Banerjee and Chattopadhyaya 2017).

Equation (8) is introduced as the adsorption kinetics model. The q_t parameter unit is the q parameter unit that changes with time and is measured in liters per second (or milligrams per gram) and t_k is the time constant of the adsorption kinetics model.

To determine the value of K_{sh} , Fig. 3B can be drawn and analyzed in terms of variable q (Fig. 4). In Fig. 4. To simplify the model, the linearity of chemical absorption (the part of absorption that happens before $q_{threshold}$) was omitted. Although there was not much error in the equation, a detailed analysis of the absorption curve can lead to a more accurate definition of the K_{sh} value.

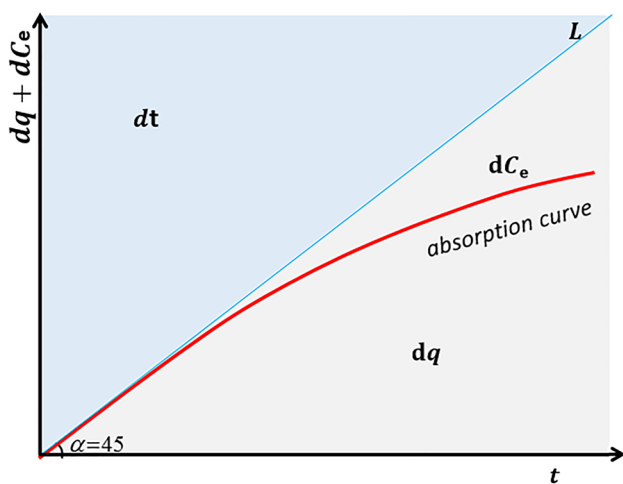


Fig. 4 Absorption time form: Relationship between absorption components and time

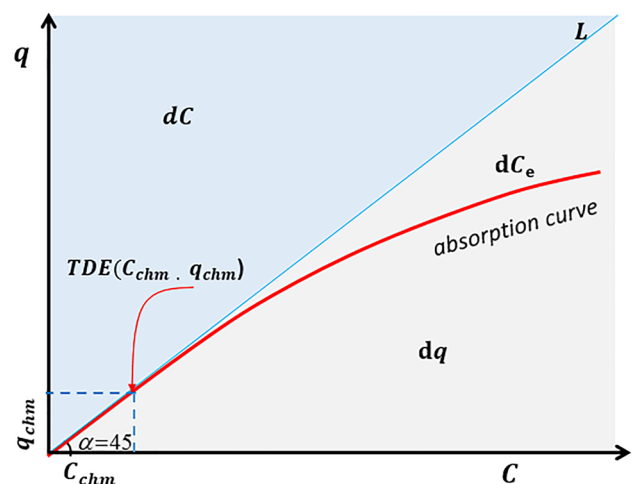


Fig. 5 Threshold of dynamic equilibrium in the absorption conceptual curve

For this, consider Fig. 5. When C tends to C_{chm} (or q tends to q_{chm}), C_e tends to zero (Threshold point). In this case, the model (7) is displayed as below.

$$q_{\text{chm}} = q_{\text{max}} \frac{C_{\text{chm}}}{K_{\text{sh}} + C_{\text{chm}}} \quad (9)$$

C_{chm} and q_{chm} parameters are chemical absorption capacity (Shamohammadi et al 2022) and are fixed values. Note: the unit C_{chm} and q_{chm} should be considered the same, for example, both in terms of milligrams per gram or milligrams per liter.

In this case, by moving the parameters, the value of K_{sh} is equal to $q_{\text{max}} - q_{\text{chm}}$. In other words, the value of K_{sh} is the Maximum physical absorption (Physical absorption capacity, q_{emax}). As a result, models (7) and (10) are modified as follows. Also, in Fig. 5, the chemical, physical and overall structure is shown.

$$q = q_{\text{max}} \frac{C}{q_{\text{emax}} + C} \quad (10)$$

$$q_t = q_{\text{max}} \frac{t}{t_{q_{\text{emax}}} + t} \quad (11)$$

Equation 10 is the "mass form" of the model, which is similar to Shamohammadi's adsorption isotherm model (Shamohammadi et al. 2022). Equation 11 is also the "temporal form" of the model, which is called the "new adsorption kinetics" model. As can be seen, Eqs. 10 and 11 are similar only in terms of their general form, but they are completely independent in terms of the characteristics of the data used. In other words, any number can be used with any measurement unit for model 10. This is also true for Model 11. What is important is the behavioral model and the final curve, which will be the same for both. Also, in Eq. 11, $t_{q_{\text{emax}}}$ is the time to reach the physical capacity of the absorber.

Materials and methods

Absorbent preparation

Blowly sand was used as an inexpensive adsorbent (to compare the adsorption capacity of an inexpensive natural adsorbent) along with activated carbon adsorbents. Therefore, first, windblown sand (with an average diameter of 0.137 mm) was prepared from the desert areas of Iran. Then it is washed and after drying it in the oven, its chemical composition, which was reported by Shamohammadi et al. (2013) based on weight percentage, is presented as follows.

Quartz (64.3%), calcite (8.1%), clay (4.6%), orthose (3.9%), biotite (3.6%), gypsum (3.4%), obsidian (3.0%), muscovite (2.2%), orthoclase (1.4%) and chlorite (0.9%).

Also, methylene blue absorption method was used to measure the specific surface area of the adsorbent. In this method, concentrations of 1, 5, 10, 15, and 20 mg/L of methylene blue were prepared in order to prepare a calibration chart, and their concentration was measured and recorded by jenway spectrophotometer, model 6300 with a wavelength of 600 nm, then 1 g A solution of 17.6 mg/L methylene blue was poured from the adsorbent and placed on a shaker at a speed of 150 revolutions per minute. After 60 min, the remaining solution was poured into special containers and placed in a centrifuge for 5 min at a speed of 3,600 revolutions per minute for sedimentation (Popescu 2022). Then the solutions were removed from the device. Their final concentration was measured and by the relation $S_{\text{MB}} = (N_{\text{g}}^* a_{\text{MB}}^* N^* 10^{(-20)})/M$, the specific surface area of the wind sand adsorbent was 12.66 square meters per g was calculated. SMB of the specific surface area in square meters per gram (Shamohammadi et al. 2022). N_{g} , the number of methylene blue molecules that are in the absorption surface layer. a_{MB} , the area occupied by methylene blue molecules which is equal to 97. 2A' and N is Avogadro's number ($1022 \cdot 6.022/\text{mol}$). M is the molecular weight of methylene blue (373.9 g/mol).

On the other hand, because the main purpose of the research is to remove heavy elements, two types of known activated carbon (Jacobi 2000 granular activated carbon and Iranian granular activated carbon) were purchased. The characteristics of activated carbon adsorbents are shown in Table 1. From now on, for brevity, Jacobi 2000 Granular Activated Carbon Adsorbent and Iran Granular Activated Adsorbent will be called "Jacobi Carbon" and "Iranian Carbon" respectively.

Preparation of solution

In this study, Titrazel ions of Fe^{2+} , Pb^{2+} , Cr^{6+} , Ni^{2+} , Cd^{2+} and As^{2+} (purchased by Merck, Germany) with a purity between 95 and 99% were used to prepare the standard solution. Deionized water was used to make the stock solution (1000 ppm) according to the standard methods of water and wastewater laboratories (Standard Methods for Water and Wastewater Examination).

Kinetic experiments: based on kinetic experiments, the optimal pH values for the absorption of heavy metals by windblown sand were between 5 and 6, and in the rest of the experiments, the pH was between 6 and 7 (Shamohammadi et al. 2022). Also, to determine the absorption kinetics model and introduce the capacity of the adsorbents, the number of 10 Erlen was chosen and Pb^{+2} metal solution with a concentration of 20 mg/L was poured into each of

Table 1 Commercial specifications of Iranian carbon and Jacobi carbon (Shamohamadi et al., 2013)

Specifications	Iranina Carbon	Jacobi Carbon
Mesh 20*50 (average geometric diameter of particles (mm))	0.575	0.575
Porosity index (mg/g)	650	950
Maximum humidity (%)	5	5
Total ash content (%)	15	13
Minimal wetting (%)	95	95
Minimum hardness (%)	95	95
Special surface (m ² /g)	500	1000
Methylene blue number (mg/g) or indicates the ability of activated carbon to adsorb medium molecules	120	480
Total pore volume (cm ³ /g)	0.38	1.04
Water solution ash (%)	0.2	0.2
Apparent density (kg/m ³)	660	490

them. Also, 0.1 g of AC-Jacobi adsorbent was poured into each of the flasks and placed on the shaker. After the passage of different times (from zero to 420 min), the solution was removed from the shaker. Then the remaining solution was passed through a Whatman sieve and the concentration of Pb⁺² remaining in the solution was measured. This work was repeated for the rest of the metals and adsorbents (at temperature). As mentioned earlier, in this method, there is no need to determine the equilibrium time (Shamohammadi et al. 2023b), but to compare the absorption isotherm curves and absorption kinetics, the equilibrium time obtained in (previous experiments) was used. Equation (12) is also used to calculate the absorption efficiency.

$$E\% = \left(\frac{C_0 - C_e}{C_0} \right) * 100 \quad (12)$$

To compare pseudo first order Lagergren and pseudo second order Ho et al. (Al-Ghouti and Da'ana 2020; Bujdák (2020) absorption kinetic models with the new model, the models were fitted on the results of kinetic experiments and the results were studied based on statistical indicators..

Isothermal experiments: For adsorption isotherm experiments, 10 Erlenmeyer was selected for each adsorbent and the solution containing heavy metal was brought to a volume of 100 ml along with 0.1 g of adsorbent (1 g/L). The initial concentration of heavy metals was considered variable and

between 20 and 200 mg/L. The pH was kept at the optimal pH level and the equilibrium time was 420 min based on kinetic experiments. All experiments were performed at temperature (between 18 and 22 °C). Each experiment was repeated three to four times. And the results were presented based on the average numbers obtained.

To study the adsorption isotherm, the mass form of the equation (based on variable *C*) was fitted to the data of the adsorption isotherm and the results of the new model were discussed with the Shamhamadi isotherm model. Also, statistical indicators of determination coefficient (*R*²) were used to evaluate the model.

$$q = q_{\max} \frac{C}{q_{\max} + C} \quad (13)$$

Table 2 Adsorption kinetic models

Mathematical model	Model	Reference
$q_t = q_e \left[1 - \frac{1}{e^{k_1 t}} \right]$	Pseudo first order (Lagergren model)	Benjelloun et al. (2021)
$q_t = \frac{k_2(q_e)^2 t}{1 + q_e k_2 t}$	Pseudo second order	Benjelloun et al. (2021)
$q_t = q_{\max} \frac{t}{t_{e\max} + t}$	New Model	Current model

Table 3 Parameters of adsorption kinetic models

Title	Parameter	Title	Parameter
Amount of adsorption (mg/L)	q_t^*	Adsorbent capacity (mg/L)*	q_{max}
Time(mine)	t		t
Absorbent equilibrium capacity (mg/L)	q_e^*	Maximum equilibrium absorption or maximum physical absorption (mg/L)*	q_{emax}
Lagergren Coefficient		Lagergren Coefficient	K_t
Time to reach the physical capacity of the absorber	t_{qemax}	Adsorption equilibrium concentration (mg /L)	C_e
Adsorption constant in Shammohamdi model (mg/L)	K_{sh}	Amount of adsorption (chemical and physical) (mg/gr)	q

*Here we have written the capacities in mg/L. This is for simplicity. In any case, it can always be converted to mg/g

Parameter C is the initial concentration of the solution or dynamic mass (in milliliters) and q is the amount of absorption of the substance on the adsorbent surface (in milligrams per gram or milligrams per liter).

The Langmuir model is not able to estimate the adsorbent capacity (in three physical, chemical and total levels) due to the use of the principle of chemical balance (equal absorption and desorption speed) (Shamohammadi et al. 2022). Therefore, the Langmuir model was not used for comparison.

Table 2, Adsorption kinetic models and Table 3 shows the parameters of the models.

Model evaluation

About half of the test data was selected for calibration and the other half for evaluation (Nash and Sutcliffe 1970). Then, according to the chart in the Fig. 5, the stages of calculating the adsorbent capacity (chemical, physical and total) and evaluating the model were done. For evaluation, three evaluation criteria including determination coefficient (R^2) and root mean square error (RMSE), were used (Eqs. 14 and 15).

$$R^2 = \left(\frac{\sum_{i=1}^N (Q_{obs} - \overline{Q_{obs}})(Q_{sim} - \overline{Q_{sim}})}{\sqrt{\sum_{i=1}^N (Q_{obs} - \overline{Q_{obs}})^2 (Q_{sim} - \overline{Q_{sim}})^2}} \right)^2 \tag{14}$$

$$RMSE = \sqrt{\frac{1}{N} \sum_{i=1}^N (Q_{obs} - Q_{sim})^2} \tag{15}$$

where Q_{obs} is the amount of observed runoff, Q_{sim} is the amount of simulated runoff (model) and N is the number of data.

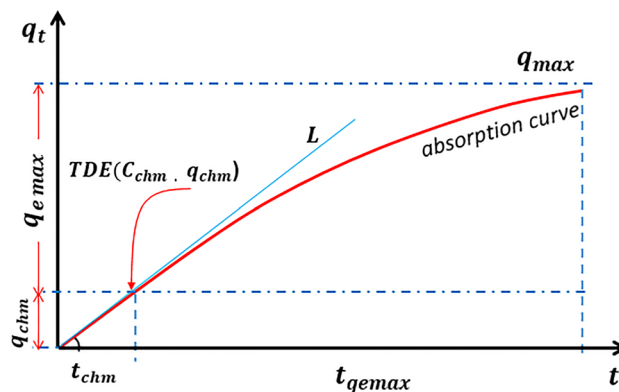


Fig. 6 Schematic of adsorption kinetic curve and values of chemical, physical and total adsorption capacity (horizontal axis by time)

Discussion

Figure 7 shows the fitting of the models of Lagergren, Ho et al. (Benjelloun et al. (2021)) and the "new model" on the test data. As can be seen, the curves of all three models for the absorption of all elements are almost coincident. Only the Lagergren model underestimates the extreme values of the laboratory data. In other words, as time increases, absorption values become less than estimated. In general, the coefficient of determination (R^2) for all models is good and close to each other ($R^2 > 0.980$). Also, for all models, the RMSE value is also very good ($4.134 > RMSE > 0.565$). The value of RMSE, only for Fe metal absorption, by Blowy sand (in the Lagergren model) is equal to 4.134.

For further comparison, the value of the total capacity, q_{max} (new model) and the equilibrium absorption value, q_e (models of Lagergren and Ho et al.) are shown in Fig. 7. As mentioned, the estimate of q_e by the Lagergren model (1898) is "less" than the estimate of q_{max} (by the new model) and the estimate of q_e by Hu et al.'s (1999) model, while according to Fig. 6 of the Lagergren kinetic curve, in Small indicates higher estimates than the new model (and test data). The reason for this behavior is related to the sentence

Fig. 7 Fitting of absorption kinetics models (new model, lagergren model and Ho et al. model) on absorption kinetics data

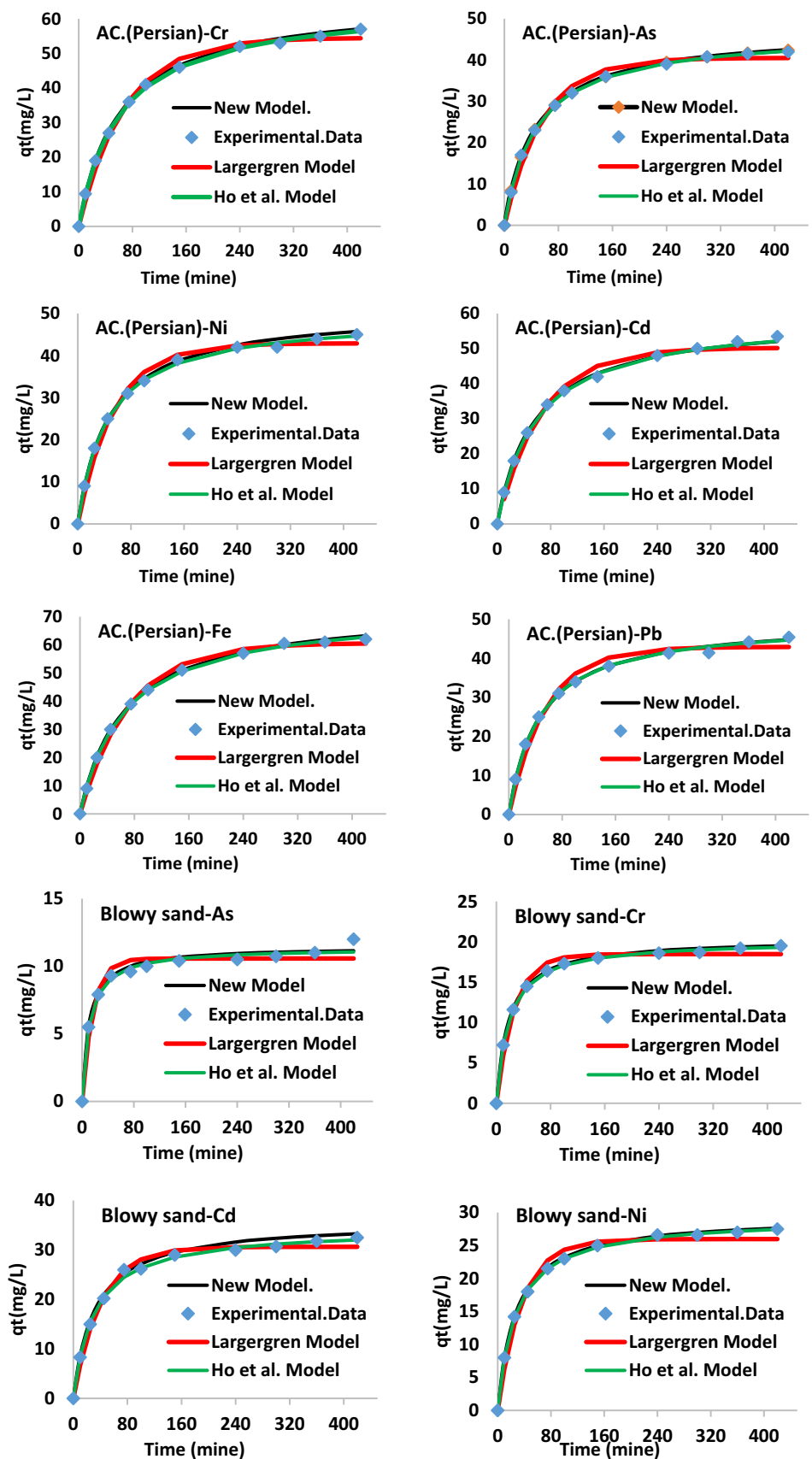
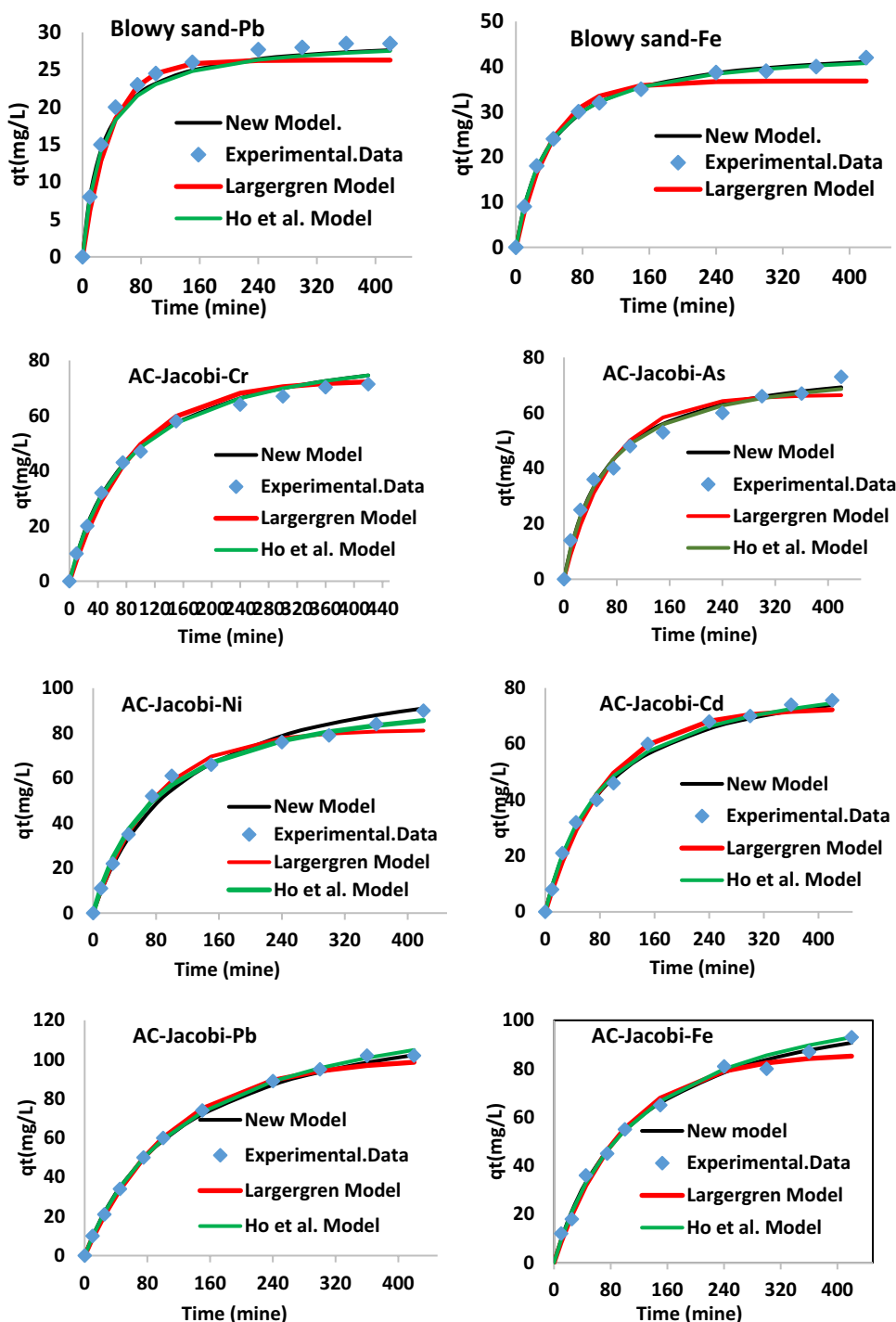


Fig. 7 (continued)



$(\frac{1}{e^{k_1 t}})$. Because as the value of t increases, the value of $(\frac{1}{e^{k_1 t}})$ (in the Lagergren equation) decreases exponentially, as a result, when t tends to infinity, the value of q_t increases more strongly (compared to the two new models and Ho et al.) decreases. This issue can be seen better compared to Ho et al.'s model (see Fig. 6). Ho et al.'s model (in small values) has much closer results than the Lagergren model, but at the end of the curve, the Lagergren model shows lower values.

Figure 7 confirms that in all experiments, the Lagergren model underestimates the values of q_e . While the comparison of Ho et al.'s model with the "new model" shows that Hu et al.'s model and the new model are very similar. The average absorption capacity of elements in Ho et al.'s model is 1.4% lower than the average absorption capacity of elements in the "new model". The biggest difference is 8.7% in Fe absorption by AC-Jacobi and the lowest difference is 0%.

The main reason for the harmony between the "new" model and the "Ho et al. model" is related to the similarity in the form of these two models. In Ho et al.'s model, if the numerator and denominator of the fraction are divided by " $q_e k_2$ ", the model of Ho et al.

$q_t = q_e / t \left[\left(\frac{1}{q_e k_2} \right) + t \right]$ appears, which is quite similar to the form of the new model. Only in the new model, instead of $\frac{1}{q_e k_2}$, the physical capacity ($q_{e\max}$) is used: $q_t = q_{\max} (t / (q_{e\max} + t))$. On the other hand, the most important difference between Ho et al.'s model and The new model is that Hu et al.'s model is written based on the equilibrium concentration (C_e), while the new model is written based on C_0 . Therefore, Hu et al.'s model is not able to calculate q_{chem} and $q_{e\max}$. In fact, it can only calculate the value Calculate q_e , which is equivalent to q_{\max} (in the new model). Chemical capacity (q_{chem}) and physical capacity ($q_{e\max}$) were first introduced by Shamohammadi (2022).

The issue that needs to be mentioned is the relationship between q_e and q_{\max} values. According to the equations in Table 2, the values of q_e and q_{\max} are theoretically equal and have no difference. Because both q_e and q_{\max} are obtained through limit values (when the value of t goes to infinity). The only difference between these two parameters is that when kinetic experiments are performed, a number must be chosen for the equilibrium time. In this case, the q_e value equal to the equilibrium time in the laboratory is obtained. In other words, the value of q_e is the

same as q_{\max} in theory, but in practice it is introduced as q_e . In this study, we compared the theoretical values of q_e and q_{\max} . It seems that it is better to use q_{\max} instead of q_e in Ho et al.'s equation.

Figure 8 shows the comparison between the equilibrium absorption capacity (q_e) and the maximum absorption capacity (q_{\max}) between the models of Lagergren (1998) and the new model.

The agreement of the new model with the models of Ho et al. and Lagergren, as well as its degree of agreement with the experimental data, shows that the new model, despite being obtained through the law of conservation of mass ($\partial M / \partial M = 1$), But it has a good fit with the adsorption kinetics data. In other words, the similarity of the new model with the absorption kinetic models (especially Hu et al.'s model) showed that our method was the right one. In other words, although we did not use the time parameter in building the model, but by replacing t with C , we obtained a kinetic model that is completely similar to Hu et al.'s model and fits well with the adsorption kinetic data.

As mentioned earlier, the new kinetic model is the result of changing the variable c to t , which has finally led to the transformation of "adsorption isotherm model" into "adsorption kinetic model". This result confirms the opinions of Leibniz, Einstein, Rowley, Barbour and Wheeler-DeWitt (Alley 1979; Verma and Bose 2017). In fact, we were able to scientifically confirm the general theories of physicists through chemical experiments.

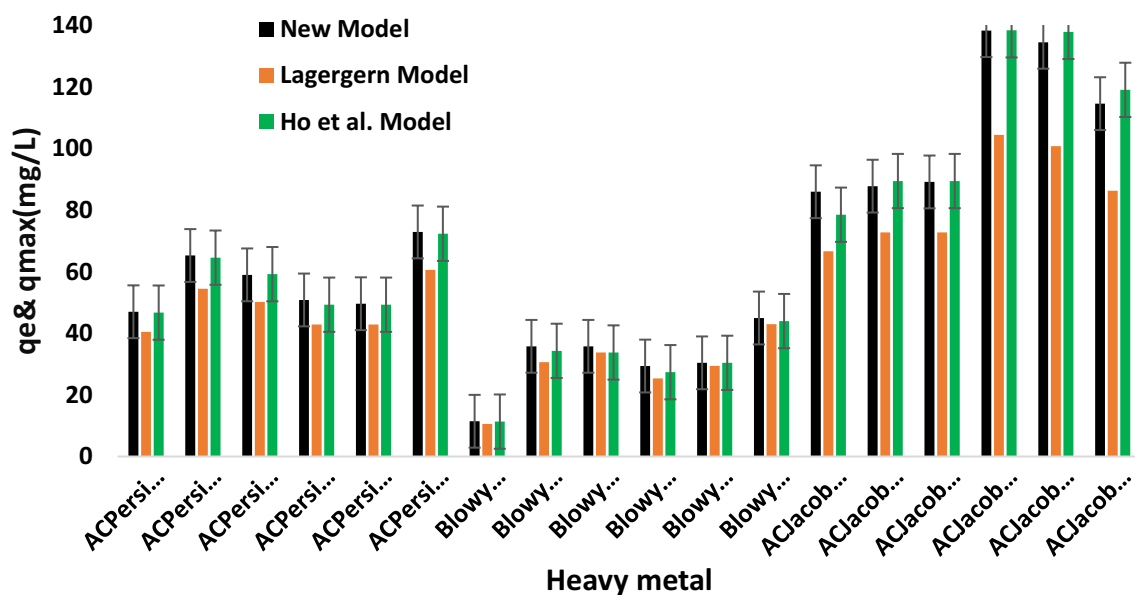
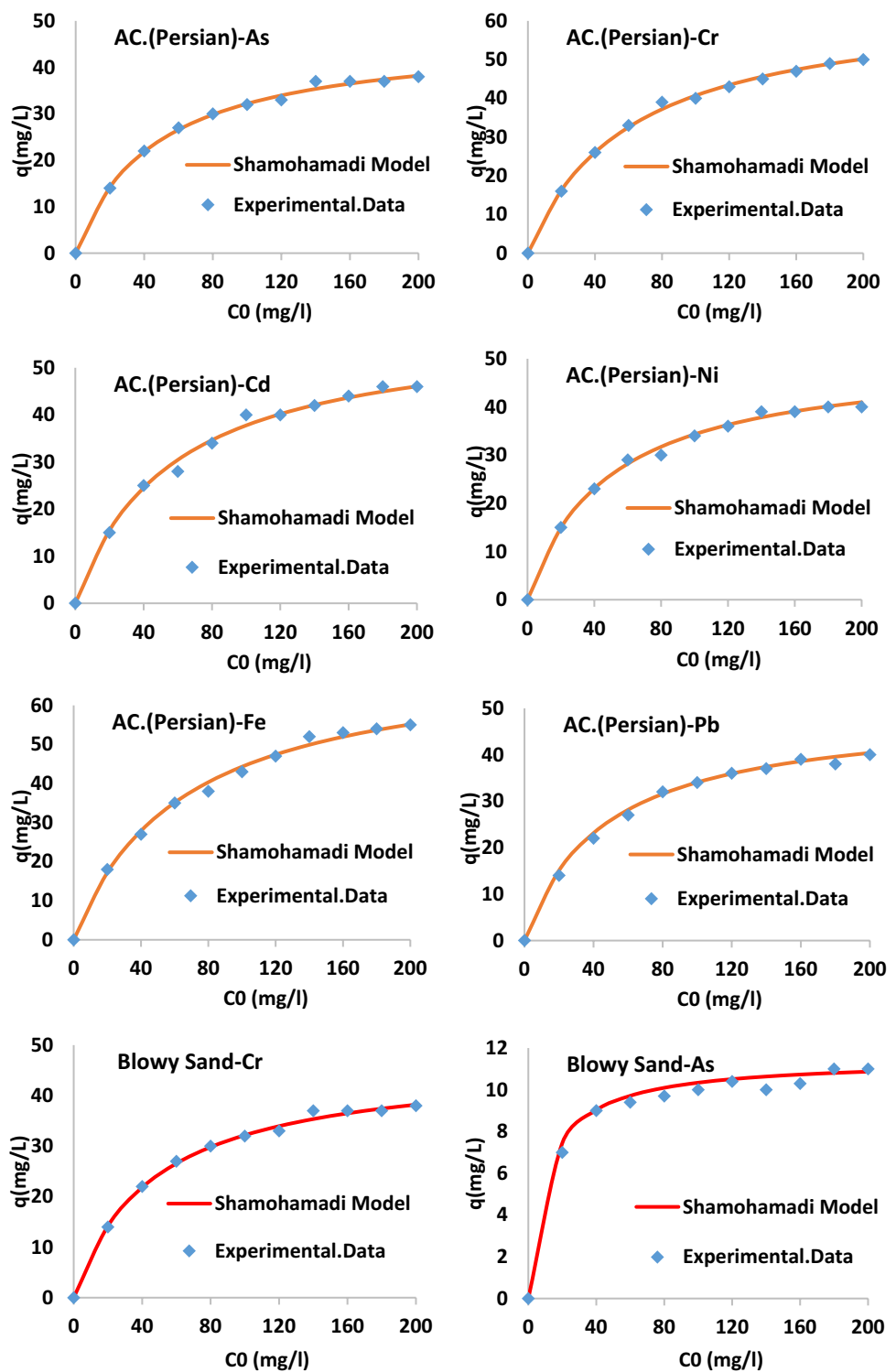


Fig. 8 Comparison between equilibrium absorption capacity and maximum absorption capacity between the models of Lagergren (1998) and the new model

Fig. 9 Fitting the Shamohamadi isotherm model (equivalent to the new isotherm model) on the absorption data

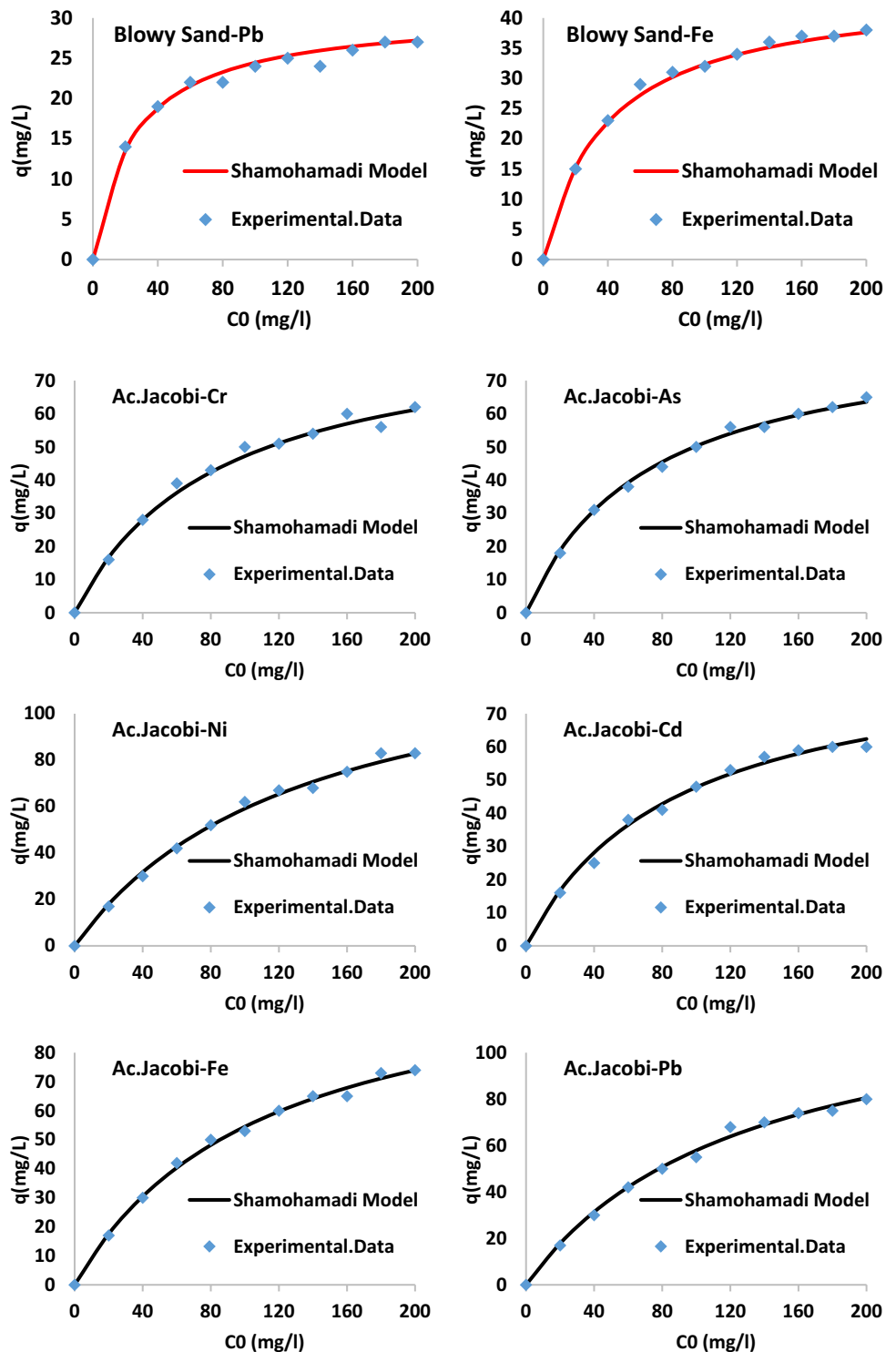


To explain further, the "mass process" happens naturally, we just need to align the time of the experiment with the "mass process". Currently, this work is done, that is, the coordination of time changes with mass changes. Many chemists have experienced that in kinetic experiments, first ΔT s are considered small and gradually ΔT s are considered

large (Shamohammadi et al. 2023b). In other words, they coordinate time changes with mass changes. What we did is to consider the coordination of time changes corresponding to mass changes (t Equivalent C).

As can be seen (Table 2), no coefficient (eg k) has been used in the new model. In the new model, instead of using

Fig. 9 (continued)



coefficients, physical absorption (maximum equilibrium capacity) has been used, which shows the accuracy of the modeling method. Because when coefficients such as k are used, it can be justified in a wide range, but when important absorption quantities such as q_{emax} are used instead of the coefficient.

As mentioned earlier, using the law of mass-time equivalence, dynamic mass equation can be written in two forms: "mass" (adsorption isotherm) and "time" (adsorption kinetics). The format of the models is completely similar, only in model 10 the independent variable is C and in model 11 the independent variable is t . To show that the results of

Table 4 The results of estimation of absorption capacity by the new absorption kinetics model (temporal form of the model) and Shamohammadi adsorption isotherm model (mass form of the model) along with evaluation indicators

Absorbent	Heavy metals	pH	Results of the new kinetic model (time form)			Results of the Shamohammadi isotherm model (mass form)				
			q_{max}	RMSE	R^2	q_{max}	q_{emax}	q_{chem}	RMSE	R^2
AC.(Persian)	As	6–7	47.041	1.562	0.997	47.578	45.782	1.796	1.56	0.998
	Cr	6–7	65.322	2.031	0.995	65.543	60.172	5.371	2.034	0.996
	Cd	6–7	59.034	1.327	0.998	59.789	56.238	3.551	1.367	0.995
	Ni	6–7	50.871	0.995	0.997	51.027	48.386	2.641	0.995	0.997
	Pb	6–7	49.651	0.762	0.993	49.921	46.383	3.538	0.752	0.993
	Fe	6–7	72.983	1.423	0.998	73.033	64.978	8.055	1.423	0.998
Blowy Sand	As	5–6	11.453	1.542	0.964	11.453	10.762	0.691	1.542	0.966
	Cr	5–6	35.804	1.892	0.969	35.804	31.89	3.914	1.992	0.97
	Cd	5–6	35.804	2.031	0.996	36.140	31.892	4.248	2.531	0.997
	Ni	5–6	29.402	2.142	0.995	30.002	26.932	3.07	2.146	0.994
	Pb	5–6	30.44	2.101	0.996	30.670	25.401	5.269	2.168	0.996
	Fe	5–6	45.012	1.402	0.997	45.012	39.245	5.767	1.452	0.997
AC. Jacobi	As	6–7	86.045	0.553	0.999	86.545	73.231	13.314	0.553	0.998
	Cr	6–7	87.854	1.942	0.995	87.033	84.369	2.664	1.942	0.995
	Cd	6–7	89.23	1.032	0.988	89.730	87.69	2.04	1.532	0.987
	Ni	6–7	138.391	1.231	0.997	138.554	134.41	4.144	1.031	0.987
	Pb	6–7	134.61	1.322	0.997	132.342	128.554	3.788	1.022	0.987
	Fe	6–7	114.669	1.431	0.973	115.021	111.071	3.95	1.462	0.983
Max			138.391	2.031	0.999	138.554	134.410	13.314	2.531	0.998
Min			11.453	0.553	0.973	11.453	10.762	0.691	0.553	0.966
Average			65.756	1.431	0.998	65.844	61.466	4.378	1.528	0.991

both models are similar, the fitting curves of Eq. 10 (mass form) on the absorption data are shown in Fig. 9. Also, the results (chemical, physical and total capacity) obtained from two models 12 and 11 are compared in Table 4. Figure 9 shows that the adsorption isotherm model has a good fit with the experimental data and the evaluation results ($0.966 \ll R^2 \ll 0.999$) and $1.528 \ll RMSE \ll 2.531$) confirm it well.

The similarity of the kinetic curves (Fig. 7) with the absorption isotherm curves (Fig. 9) obtained in completely independent experiments testify that the results of the experiments (regardless of the models) have similar curves (regardless of Catch). Similarity of Ho et al.'s models with Shamhammadi's isotherm model. This in itself is an important reason to say that one model is sufficient to represent both experiments (the kinetic curves in both figures are indicated by dashed dots). In other words, it can be said: "For accuracy in the model, it is necessary to write the mass-mass model, then use the law of mass-time equivalence."

Because the mass model (Eq. 11) is the same as the Shamohammadi isotherm model (Shamohammadi et al. 2022), it will be used as the Shamohammadi model from now on.

To check the physical, chemical and total capacity of the adsorbents, first the chemical capacity of the adsorbents was obtained from the difference between the total capacity and the physical capacity of the adsorbent ($q_{chem} = q_{max} - q_{emax}$). Then the results along with the evaluation indices (R^2 and RMSE) were written in Table 4 (q_{emax} and q_{max} are obtained using the model).

Table 4 results of applying the absorption kinetics model for the absorption of heavy metals (Fe^{2+} , Pb^{2+} , Cr^{6+} , Ni^{2+} , Cd^{2+} and As^{2+}) by AC adsorbents. Persian, Blowy Sand and AC. Jacobi shows. As can be seen, he results related to the whole adsorbent in the absorption of metals by two methods (models) of adsorption kinetics and adsorption isotherm are the same. Also, the absorption (total capacity) for both models is related to the AC absorber. Jacobi in Ni adsorption is 138.391 mg/L. The lowest absorption capacity is related to the Blowy Sand absorber in Ac absorption and is equal to 11.453 ml g/L. Sun size is the same for both models and equal to 65.756 g/L. Also, the comparison of absorbents shows that absorbent capacity for all heavy metals in the form of Blowy Sand AC. Jacobi > AC. Persian > is Several factors play a role in the absorption capacity, but the most important factor is the absorption capacity of the special surface (m^2/g), which is for, AC. Persian and Blowy Sand AC. Jacobi is equal to 1000, 500 and 12.66 square/gram,

respectively. These results are consistent with the results of studies by Shamohammadi et al. (2013) and Shamohammadi et al. (2022).

Comparison of the capacity of AC absorbers. Persian and Blowy Sand AC. Jacobi for the absorption of heavy metals (Fe^{2+} , Pb^{2+} , Cr^{6+} , Ni^{2+} , Cd^{2+} and As^{2+}) by Shamohammadi et al. (2022) shows that the Langmuir model shows an average of 70% lower absorbent capacity than the Shamohammadi model.

In Table 4, the values of absorbent capacity (q_{max} , q_{chem} , q_{chem}) estimated by (1) Shamhammadi isotherm model (model mass figure) and (2) total capacity of adsorbents estimated by the new model (time model model) are shown. The evaluation of the models shows that the values obtained in both models and for all absorbers are well described ($0.991 \ll R^2 \ll 0.998$) and $0.553 \ll RMSE \ll 2.531$).

To further examine the results of the new model, the physical adsorption capacity was shown with the results of the Shamohammadi adsorption isotherm model (Eq. 13) in Fig. 10. The very good coefficient of determination (0.998) between q_{emax} (in the kinetic model) and q_{emax} (in the isotherm model) shows that the output of the new model, in addition to being consistent with the output of the kinetic

model (Hu et al.), is also consistent with the output of the isotherm model. Shamoahmmadi's recruitment is also coordinated. In fact, the basis of both the Shammohammadi isotherm model (Shammohammadi et al. 2022) and the new kinetic model are the same. In the new model, the same steps of the Shamohammadi model are written step by step. The difference between the new kinetic model and the Shamohammadi adsorption isotherm model (Shamohammadi et al. 2022) is two things:

- (1) Using the "dynamic mass equation" and "time-mass equivalence law" to convert the adsorption isotherm model to the adsorption kinetics model (both of which are presented for the first time in this study).
- (2) By using the "new kinetic model", there is no need for experiments to determine the equilibrium time, because the new kinetic model directly determines the adsorption capacities (chemical, physical and total). In fact, the new kinetic model performs both the role of the isotherm model and the role of the adsorption kinetic model. Therefore, by using the new model, the goals of adsorption studies (absorption kinetics and adsorption isotherm) can be achieved with the least number of experiments and the least cost (Fig. 10).

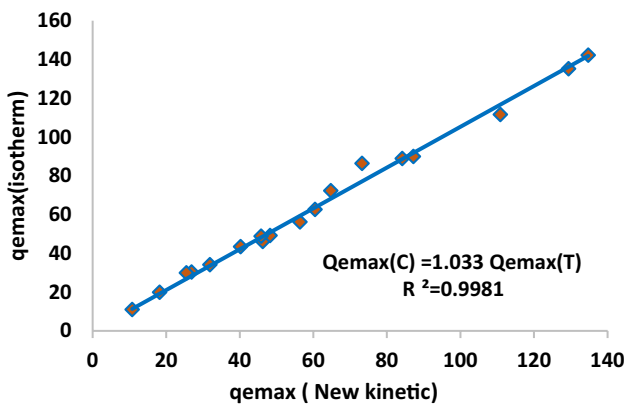


Fig. 10 The relationship between the physical adsorption capacity of the new kinetic model and the results of Shamhammadi's adsorption isotherm model

One of the reasons that the physical capacity of the "new model" was not compared to the Langmuir model is that the Langmuir model was written based on the principle of chemical equilibrium ($\partial M/\partial t = 0$). Shamohammadi et al. (2022) reported that the principle of chemical balance is based on the lack of mass transfer, because in the principle of chemical balance, the speed of going (adsorption) and returning (absorption) is equal. In other words, for the balance of two elements A and B, the relation $-\frac{d[A]}{dt} = \frac{d[B]}{dt}$ is supposed (Aseel et al. 2017) as a result $0 = \frac{d[A]}{dt} + \frac{d[B]}{dt}$ or $0 = \frac{d([A]+[B])}{dt}$. The meaning of the last term is that $0 = \frac{d(M)}{dt}$ means the mass changes on the absorbent surface (mass transfer) in an absorption system (for example, Erlenmeyer) in equilibrium conditions is zero. In fact, in a dynamic equilibrium system, particles are only moved (absorbed and desorbed), but no particles are added to the system. Therefore,

Table 5 Mass-mass models in different scientific fields that are made by the dynamic mass equation and converted into kinetic models using the mass-time equivalence ($m \equiv t$)

1	2	3	4
Scientific field	Mass-mass model	Mass-time model	References
Water-soil	$I(cm) = FC \frac{H}{K_{sh} + H} + k H$	$I_t(cm) = FC \frac{t}{t_k + t} + k t$	Shamohammadi et al. (2023b)
Hydrology	$S(mm) = S_{max} \frac{P_a}{F_{max} + P_a}$	$S_t(mm) = S_{max} \frac{t}{t_{fmax} + t}$	Shamohammadi et al. (2023a)
Chemistry	$q(mg/L) = q_{max} \frac{C}{q_{emax} + C}$	–	Shamohammadi et al. (2022)
	–	$q_t(mg/L) = q_{max} \frac{t}{t_{gemax} + t}$	Current study

the Langmuir model, which is based on no mass transfer, cannot be used in the knowledge of absorption, which is based on mass transfer. In addition, the value of C_e in the Langmuir model is itself a function of the process and cannot be an independent change. This is also true for the rest of the isotherm models (Shamohammadi et al. 2022). Therefore, one of the disadvantages of the "closed system assumption" is that models such as the Langmuir model make mistakes (Shamohammadi et al. 2022).

Expansion of the theory of relativity of time

Table 5 shows the extension of mass-time equivalence in other sciences (hydrology and water-soil). In Table 5, mass models based on the dynamic mass equation have been converted into kinetic models using mass-time equivalence.

As can be seen, in different water-soil systems, hydrology and surface chemistry, depending on the coefficients used in the models (Table 5, column 3), the time t (input mass equivalent) for each system, according to the model of that system, The output mass is converted. In other words, it can be said: every mass-mass (or energy-energy) system has its own time, and every system is different depending on the way it is examined or under what conditions it is examined. This issue can also be expressed as follows:

Based on the definition of dynamic mass, equivalence can be defined for all mass components (input and output) in the system. As a result, it is possible to use the parameter t_t instead of I_t , S_t , and q_t in the equations of Table 5 (column 2). In this case, it can be said that t is the equivalent time of the input mass and " t_t " is the equivalent time of the system. Therefore, each mass process has a special model and a "special time". That is, like "equivalence of mass-time", "equivalence of system-time" can also be defined. For example, "absorption system time" (Table 5, column 2), is t_t in the following equation:

$$t_t(\text{min}) = t_{\text{max}} \frac{t}{t_{q\text{max}} + t} \quad (16)$$

The value of t_{max} is the time equivalent of the absorbent capacity. In fact, we use the time parameter based on our needs. In the kinetic model, when our goal was the amount of absorption based on time, we put time instead of the input mass to obtain the amount of absorption in mg/L, but when goal is to calculate the time of the system, all parameters can be calculated in terms of time. Therefore, the time in an "absorption system" in laboratory conditions is obtained from the equivalent curves of Figs. 7 or 9.

It is reminded: in the field of mass (the subject of this study), when the equivalence of mass-time (or system-time) can be used when the model of mass-mass is obtained

through the law of conservation of mass (dynamic mass equation).

For the theoretical expression of system-time, we mention the following examples: We have seen or heard many times that two people who have the same date of birth, one looks younger than the other, even if their food (input mass) is the same. be That is, in addition to the standard time, their "input mass equivalent" time is also the same, it is still possible (depending on other factors) such as genetics, lifestyle and interaction with the environment, their appearance (height, weight, agility, etc.) is not the same.

Therefore, it is as if the time has not passed the same for both of them (their system time is different). This issue is not limited to people's age, but also applies to their individual characteristics (such as obesity, white hair, or old eyes). Therefore, for each of their characteristics, a model specific to that characteristic can be checked. For example, the same two people who have the same age (according to the standard time, $9,192,631,770 \cdot \lambda = 1$ s), have experienced different times in terms of increasing their body mass. This example can be repeated for different plants and different objects. For example, the time of erosion of a piece of wood is different from the time of erosion of a piece of stone, although we compare their system time based on the standard time, but each of them interacts with the surrounding environment (depending on what direction and under what conditions) to be reviewed), they follow a certain model. Therefore, it can be claimed that the relativity of time (Alcocer 2020) is not limited only in the geometric framework, but every system in the world has its own relative time.

In this case, when it is said that the clock hands move slower in the center of gravity, the reason should be sought in the mass-energy process that causes the clock hands to rotate (Zehe et al. 2001). Many people have studied about chemical reactions in different gravities and showed that the rate of chemical reactions changed according to the increase of gravity (Pyykko 2012; Gillespie 1977; Nickerson et al. 2004; Winter et al. 2017; Lecca 2021; Michaletti et al. 2017).

To better understand the issue, we compare general relativity (the law of space-time) with the relativity of time in "equivalence of mass-time".

In general relativity (Lecca 202), gravity is considered as a geometric factor. Although the origin of space-time bending depends on energy, matter momentum and radiation (light) (Zehe et al. 2001), the relativity of time is only investigated in the framework of Riemannian geometry (Zehe et al. 2001). For this reason, the space-time interval (S) in Einstein's model is expressed as follows. Δr and Δt are the spatial and temporal difference of two events in the coordinate system, respectively, and C is the speed of light.

$$\Delta S^2 = \Delta r^2 - C^2 \Delta t^2 \quad (17)$$

In this equation, the value of t is the standard time shown by the clock, but because the hands of the clock are affected by the center of gravity or the speed of the object, the space–time equation is also a combination of the speed of light, standard time, and location parameters. In fact, Einstein wrote his model based on the speed of the clock hands. He does not comment on the mass and energy processes that cause the clock hands to turn. Meanwhile, our theory is related to mass and energy processes that cause the clock to rotate. For example, when Einstein says "time slows down as you approach the center of gravity", in our opinion, gravity affects the oxidation and reduction process of the battery (flow of mass and energy) (Winter et al. 2017; Lecca 2021), as a result of the hand The clock slows down. Or when a clock works with an atomic battery, from our point of view, the excitation process, which originates from mass and energy, is affected by gravity and speed, as a result, the hands of the clock rotate slowly or rapidly.

Basically, let's assume that instead of the cesium 133 atom, another atom was used for standard time, would the unit of time be what is currently used? Or suppose that we were to place the same Cesium 133 atom at a far distance from the center of gravity of the earth, would the unit of time remain intact? The answer is negative. The studies of Stiles and Fletcher (2002) and Winter et al. (2017) showed that the answer is negative. The reason is that the time depends on the system and the conditions in which the system is placed. The conditions can be gravity or movement speed or other actions.

So we think that the relativity of time is much more complex and extensive than the space–time model. In other words, time is woven not only in space, but also in "mass-energy" systems, so that each system experiences its own time in addition to the universal standard time.

As mentioned earlier, time does not exist independently, rather time takes its validity from the process of mass and energy. For this reason, we can use the time parameter proportional to mass (or system) changes. In this case, the issue of directionality of time (Smolin 2014) is also ruled out. But, even if we assume that time exists, the general direction of time cannot be determined based on entropy (the second law of thermodynamics). Because the basis of the knowledge of absorption is opposite to the entropy process.

In the absorption of pollutants such as odor, smoke and steam, they are absorbed on the surface and their entropy value is reduced. For example, in the hydrological cycle, steam (gas) accumulates naturally and as a result of their absorption by salt particles in the air and turns into ice particles at the dew point (precipitation production process), then it becomes heavy and due to its own weight They fall to the ground (in the form of snow or rain). Therefore, in the process of converting steam to water, entropy decreases. In

areas like the Amazon forests, evaporation and condensation occur alternately and sometimes simultaneously.

Therefore, although there are many other reasons to violate the hypothesis of time directionality, the knowledge of absorption, which is an important part of science, is in clear contradiction with Shawn Carroll's theory (Smolin 2014).

Conclusion

- The dynamic mass equation, in addition to playing a fundamental role in mass modeling (mass-mass), also prepares the ground for using the mass-time equivalence law.
- The dynamic mass equation is presented for modeling in open systems. Therefore, this equation can play a very important role in the new modeling method.
- Using the law of equivalence of mass-time in this study showed that time and the system of mass-mass are intertwined and causes the development of general relativity in systems of mass-mass (mass-energy).
- An important result that can be obtained from the combination of dynamic mass equation and mass-time equivalence is that: the law of conservation of mass can always be used for modeling in open systems ($\partial M/\partial t = 1$) and we do not have to Use the unrealistic assumption (closed system) and the law of conservation of mass in a closed system ($\partial M/\partial t = 0$).
- Modeling adsorption kinetics based on the "dynamic mass equation" ensures that both the objectives of adsorption isotherm models and the objectives of adsorption kinetics models are met. In this way, time and money are saved.
- The present study showed that if the initial concentration of the solution is used as an independent variable in the adsorption isotherm model, the values of chemical adsorption and physical adsorption are calculated separately.
- Comparison of kinetic curves, absorption capacity and absorption rate showed that the new kinetic model is fully compatible with the model of Hu et al. And these two models have the same form.
- Comparing the format of the isotherm model resulting from the dynamic mass equation in this research showed that this model is completely consistent with Shammohammadi's isotherm model.

Author contribution SS designed the study, software, conceptual modeling, wrote the manuscript (drafts and original) and revised it (95%). BS, software (less than 5%).

Funding Funding information are not applicable. No funding was received. No grants were received.

Data availability All the data, including the experimental measurements, the data used for formulating empirical relations, and the code processing the data that support the findings of this study, are available from the corresponding author upon reasonable request.

Declarations

Conflict of interest There is no conflict of interest.

Consent to publish All authors agree to publish this manuscript. There is no conflict of interest.

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