



Thesis Approval

Hydrochemical and hydrogeological investigation of the water resources of Serar Al-Janobi catchment area – Palestine

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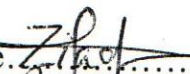
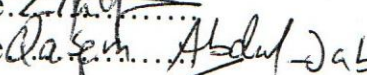

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Abstract

Serar Al-Janobi catchment area that covers an area of 25 km² represents the southern part of the West Bank. It lies within 120,000-130,000 N and 160,000-170,000 E on Palestinian grid. This study conducted between (2004 - 2005) and focuses on the hydrogeological and hydrochemical of the springs in Serar Al-Janobi catchment area.

The average rainfall depth over the study area between 1975 and 2005 was 562.9 mm/y. The average rainfall depth over Wadi Fukin, Hussan, Battir, Wadi Sakaran, and Nahhalin catchments is 561.6 mm/y, 558.9 mm/y, 559.8 mm/y, 567.4 mm/y, and 574 mm/y respectively. The average potential and actual evapotranspiration is 1132 mm/y and 302.2 mm/y respectively. The average runoff was calculated to be 73.6 mm/y to 90.6 mm/y (13%-16% of the average annual rainfall), while the average recharge was calculated to be 108.6 mm/yr (corresponds 19.3 % of the annual rainfall). The aridity indices classifying Serar Al-Janobi catchment area as sub-humid. The change in soil moisture, depression storage, and interception of Wadi Fukin area was estimated to be 70 mm/yr.

The study area encompasses 11 springs that are fed by local, perched, unconfined aquifers, which are completely separated from regional aquifers. The recharge area of the water that feeds the springs is limited to the topographic water divide.

Springs in the study area are divided into three water flow systems. Type I includes the springs of Al-Balad [Battir], Jam', and Faris which are characterized by a highly connected rocks (conduit), high hydraulic conductivity (5-8 m/d), and high (λ) $>$ ($5.0 * 10^{-3}$). Type II includes Al-Balad [Nahhalin], Al-Skhona, Al-Balad [Wadi fukin], and Al-Namoose springs which are characterized by medium connected rocks (fractured), medium (λ) between $5.0 * 10^{-3}$ and $4.0 * 10^{-3}$, and medium hydraulic conductivity (3-3.6 m/d). Type III includes Al-Quds, Al-Teenah, Um deek, and Sadiq springs which are characterized by a low connected rocks (porous), low (λ) $<$ ($4.0 * 10^{-3}$), low hydraulic conductivity (1-2 m/d). The change in water head for all springs ranges from 0.74-2.9 m, while transmissivity ranges from 2.2-34 m²/d. The water volume stored above the springs level (V) of Al-Balad [Battir], Jam', and Faris, Al-Balad [Nahhalin], Al-Skhona, Al-Balad [Wadi fukin], and Al-Namoose, Al-Quds, Al-Teenah, Um deek, and Sadiq springs was estimated to be 53052.6 m³, 26584.6 m³, 15247 m³, 12055.8 m³, 2592 m³, 6111.2 m³, 2260.5 m³, 5095.3 m³, 1729.7 m³, 1570.9 m³, and 1188 m³ respectively.

The springs hydrograph and hydrochemical study, which involved collection and analysis of ground water samples from the springs, showed that the rain water is the only source of ground water recharge. Mixing with the waste water leaking from the poorly designed cesspits, Infiltration of leachates from washing the piles of animals dung, fertilizers by the rainfall in winter is responsible for the contamination of spring's water. On Piper diagram the ground water samples plots in the area of normal earth alkaline water with prevailing bicarbonate and with prevailing sulfate and chloride, and earth alkaline water with prevailing bicarbonate. Durov diagram shows that 9 % of the samples plots in field (5) indicating a mixing with waste water or simple dissolution of carbonate minerals, 40.9 % of the samples plots in field (1) which dominated by Ca⁺² and HCO₃⁻ ions, frequently indicates recharging water in limestone, and 27.2 % of the samples fall in field (2) which are dominated by Ca⁺² and HCO₃⁻ ions, in association with dolomite if Mg⁺² are significant. However, those samples in which Na⁺ is significant, an important ion exchange is presumed. Springs in study area characterized by one type of seasonal variation in water

quality. This type shows that springs water have high concentration of ions in winter than in summer.

Cluster analysis and Collins diagram classified the samples into two main groups and six subgroups. Group A includes 72.7% of the samples with average EC of 684.69 $\mu\text{S}/\text{cm}$, where as group B includes 27.3% of the samples with average EC of 963.33 $\mu\text{S}/\text{cm}$. Group A1 (includes samples of Al-Quds spring) characterized by its lowest concentration of solutes than the others groups, group A2 (includes samples of Al-Balad [Nahhalin], Faris, Jame', Sadiq, Al-Balad [Battir], Um-deek, Al-Namoose, Al-Balad [wadi fukin]) characterized by its highest concentration of ions than group A1. Group A2a includes samples of Al-Balad [Nahhalin] (both seasons) and Faris (winter) springs that are subject to contamination by waste water leaking from the widespread poorly designed cesspits and agricultural effluents, and its average ions concentration is higher than groups A1 and A2. Group A2b includes samples of Faris (summer), Jame' (both seasons), Sadiq (both season), Al-Balad [Battir] (both season), Um-deek (both season), Al-Namose (summer), and Al-Balad [wadi fukin] (summer) springs that are subject to contamination by waste water from poorly designed cesspits. It is characterized by the lowest concentration of solutes than group A2a. Group B1 includes samples of Skhonah (both season) spring that are located inside agricultural lands where the contamination comes from agricultural effluents. It has the highest average concentration of solutes comparing with the other groups. Group B1 includes samples of Al-Namoose (winter), Teenah (both seasons), and Al-Balad [wadi fukin] (winter). The average concentration of solutes in group B2 is higher than groups A1, A2a, and A2b but is lower than group B1.

The water hardness of 18.2 % of the samples is classified as hard water, and 81.1 % is classified as very hard water. Based on SAR and SSP values, water from all springs has low sodium (S1), excellent, and is suitable for irrigation purposes. Based on salinity (EC) classification, 31.8 % of samples are good for irrigation, 68.1 % are of less irrigation water quality.

ملخص

دراسة بحثية لهيدروجيولوجية و هيدروكيميائية مياه ينابيع حوض صرار الجنوبي

يعتبر حوض صرار الجنوبي والذي يبلغ مساحته 25 كم² الجزء الجنوبي للضفة الغربية، فهو يقع بين 120-130 شمالا و 160-170 شرقا وفقا للاحداثيات الفلسطينية. أنجزت هذه الدراسة بين عامي 2005 - 2004، حيث ركزت على تقييم هيدروجيولوجية و هيدروكيميائية الينابيع فى حوض صرار الجنوبي.

دلت العمليات الحسابية التى استخدمت بين عامي (2005 - 1975) على أن معدل سقوط الامطار على منطقة الدراسة هو 562.9 ملم/سنة، وعلى كل من حوض وادى فوكين، حوسان، بتير، وادى السكران، نحالين هو 561.6 ملم/سنة، 558.9 ملم/سنة، 559.8 ملم/سنة، 567.4 ملم/سنة، و 574 ملم/سنة على التوالي. كذلك أن معدل التبخر - نتح الكامن والتبخر - نتح الحقيقي هو 1132 ملم/سنة و 302.2 ملم/سنة على التوالي، وأن معدل الجريان السطحي بين 90.6 - 73.6 ملم/سنة والذي يعادل (% 16 - 13 من الامطار التى تهطل على المنطقة)، بينما بلغ معدل التغذية الى 108.6 ملم/سنة والذي يعادل % 19.3 من الامطار التى تهطل على المنطقة. يصل معدل بقية المياه التى تعترض فوق الاشجار والسطوح و لا تصل الى المياه الجوفية الى 70 ملم/سنة. يمكن اعتبار منطقة الدراسة شبه رطبة من خلال استخدام معاملات الجفاف المختلفة.

تتكشف فى منطقة الدراسة الصخور الرسوبية الجيرية التى تعود الى العصر الالبى وحتى الهولوسين. تشمل منطقة الدراسة 11 نبع تخرج من خزانات جوفية معلقة تكون مفصولة كليا عن الخزانات العميقة، حيث تكون مناطق التغذية لهذه الينابيع محصورة بالاحواض السطحية للمنطقة.

تتميز منطقة الدراسة بوجود ثلاثة أنظمة لتدفق المياه استنادا الى قيم الميل (معامل التخزين λ). يتميز النظام الاول بأن الصخور التى تخرج منها الينابيع تحتوى على فجوات كبيرة وبأن النفاذية تكون كبيرة، حيث تتراوح قيم معامل التخزين (λ) ومعامل النفاذية الى (5.0×10^{-3}) و 8 - 5 م/يوم. يتميز النظام الثانى بالصخور التى تكون الفجوات والنفاذية فيها متوسطة والتى تتراوح قيم معامل التخزين ومعامل النفاذية الى $10^{-3} \times (4.0 - 5.0)$ و 3 - 3.6 م/يوم، أما بالنسبة للنظام الثالث فهو يتميز بأن الفجوات والنفاذية تكون صغيرة جدا حيث تصل قيم معامل التخزين و معامل النفاذية الى أقل من $10^{-3} \times 4.0$ و 2 - 1 م/يوم. يتراوح التغير فى سطح المياه الجوفية لينابيع منطقة الدراسة بين 0.74 - 2.9 م، بينما يتراوح انتقال المياه بين 2.2 - 34 م²/يوم. يبلغ حجم المياه المخزونة لكل من ينابيع البلد (بتير)، جامع، وفارس والتى تنتمى للنظام الاول 53052.6 م³، 26584.6 م³، 15247 م³ على التوالي، أما لينابيع النظام الثانى والتى تضم كل من ينابيع البلد (نحالين)، السخونة، البلد (وادى فوكين)، و

الناموس فان حجم المياه المخزونة يصل الى 12055.8 م³, 2592 م³, 6111.2 م³, و 2260.5 م³ على التوالي. ينبع كل من القدس, التينة, ام الديك, و صديق, والتي تنتمي الى النظام الثالث فانه يبلغ حجم المياه فيها الى 5095.3 م³, 1729.7 م³, و 1570.9 م³, و 1188 م³.

استنادا الى دراسة التغير فى قيم تدفق مياه الينابيع والهيدروكيميائية التى تضمنت جمع وتحليل عينات المياه الجوفية بأن مياه الامطار هى المصدر الوحيد لمياه الينابيع, وبينت أن اختلاط المياه مع المياه العادمة المتسربة من الحفر الامتصاصية سيئة التصميم و نواتج غسل فضلات الحيوانات بواسطة مياه الامطار فى فصل الشتاء هى العوامل الرئيسية فى وجود بعض الملوثات فى مياه الينابيع. بالاعتماد على نموذج (Piper) معظم ينبع منطقة الدراسة ظهرت فى حقل المياه القلوية الارضية مع زيادة فى كمية البايكربونات و فى حقل المياه القلوية الارضية الطبيعية مع زيادة فى كمية البايكربونات والنترات والسلفات لبعض الينابيع. أظهر نظام (Durov) للتصنيف بأن % 9 من العينات تقع فى حقل (5) التى تشير الى خلط مع المياه العادمة أو تحلل الصخور الجيرية, وأن % 40.9 تقع فى حقل (1) التى تكون فيها أيونات الكالسيوم والبايكربونات أكثر شيوعا, و % 27.2 تقع فى حقل (2) التى تشير الى أن أيونات الكالسيوم والبايكربونات تكون شائعة.

استنادا الى التحليل العنقودى وشكل (Collins) تم تصنيف عينات المياه الى مجموعتين رئيسيتين و ستة مجموعات جزئية. مجموعة (A) تضمنت % 72.7 من العينات التى يصل فيها معدل قيمة (EC) الى 684.69 $\mu\text{S}/\text{cm}$, بينما مجموعة (B) تتضمن % 27.3 من العينات التى تصل فيها قيمة (EC) الى 963.33 $\mu\text{S}/\text{cm}$. تضم مجموعة (A1) عينات نبع القدس التى تتميز بتركيز أيونات أقل من المجموعات الأخرى, أما مجموعة (A2) والتى تضم البلد (نحالين), فارس, جامع, صديق, البلد (بتير), ام الديك, الناموس, والبلد (وادي فوكين) فإنها تتميز بتركيز أيونات أعلى من مجموعة (A1). تضم المجموعة (A2a) عينات ينبع البلد (نحالين) (فى الموسمين) وفارس (موسم الشتاء) التى تكون معرضة للتلوث من المياه العادمة والتدفق الزراعى, حيث يكون معدل تركيز اليونات فيها أكثر من مجموعة (A1) و (A2). مجموعة (A2b) تتضمن عينات ينبع فارس (موسم الصيف), جامع (فى الموسمين), صديق (فى الموسمين), البلد بتير (فى الموسمين), ام الديك (فى الموسمين), الناموس (موسم الصيف), و البلد وادي فوكين (موسم الصيف) التى تكون معرضة للتلوث من المياه العادمة فقط, حيث تحتوى على تركيز أيونات أقل من مجموعة (A2a). مجموعة (B1) تضم عينات نبع السخونة (فى الموسمين) الموجودة داخل الاراضى الزراعية بحيث تميزت عن المجموعات الأخرى بمعدل تركيز أيونات أكثر, بينما تميزت ينبع المجموعة (B2) والتى تضم عينات ينبع كل من الناموس (موسم الشتاء), التينة (فى الموسمين), والبلد وادي فوكين (موسم الشتاء) بمعدل تركيز أيونات أكثر من المجموعات (A1), (A2a), (A2b), و أقل من مجموعة (B1). استنادا لحسابات (SAR), (SSP), و (EC) صنفت ينبع منطقة الدراسة على أنها صالحة للزراعة. دل حساب عسر الماء للعينات

على أن % 18.2 من العينات صنفت على أنها عسرة (hard), و % 81.1 صنفت على أنها شديدة العسر (very hard).

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Chapter One

1 Introduction

The West Bank, as most of the Middle East regions, suffers from scarcity of water, which is considered to be the most precious resource in the area. The scarcity of water (caused mainly by the prevailing arid and semi-arid conditions) is a major constraint on the socio-economic human development in the area. Increasing rate of population, overexploitation, and the Israeli control on the Palestinians water resources increases the water shortage.

The study area is prevailed by deteriorated environmental conditions, such as: the uncontrolled disposal of the raw wastewater by the Israeli colonies and villages in the nearby wadis, the lack of sewer systems, and wide distribution of poor designed cesspits, which are potential source of pollution of springs in the area. All the above factors as well as the lack of the available information about the hydrology, hydrogeology, and hydrochemistry in the study area arise the need for such study.

1.1 Problem statement

The problem statement include the answer of the following question: what is the hydrogeology and hydrochemistry of groundwater resources in Serar Al-Janobi catchment area?

1.2 Objectives

The overall objective of this study is to investigate, describe, and analyse the hydrogeology and hydrochemistry of the Serar Al-Janobi drainage basin based on hydrogeological data, field measurement, field observation, and chemical analysis of ground water samples. This study will be a base for decision makers toward proper management for water resources in the area.

1.2.1. Specific goals:

- Collecting the basic data about groundwater resources such as location and flow of springs in the study area.
- Estimation of missing data such as the rainfall average, runoff, recharge, potential and actual evapotranspiration.
- Determining the different type of lithological material such as porous, fracture, and conduit based on discharge measurements and tracing the response of springs to rainfall.

- Identification the aquifers being discharged by the springs in comparison with the different lithologies that resulted from the evaluation of the discharge values of the springs.
- Determining the recharge area of each spring using theoretical method and comparing it to recharge area from the map.
- Calculating the recharge rate and volume of water stored in aquifer.
- Estimation of the physical properties of aquifers such as hydraulic conductivity, transmissivity, and saturation thickness.
- Determining of physical, chemical parameters of springs and evaluating their suitability for domestic and agricultural purposes.
- Specification of the different pollutants, their possible sources and their actual impact on the groundwater resources and to pinpoint on possible measures to improve the situation.
- Presentation of a digital terrain model and basic maps of the area such as the landuse, drainage system, and exposed aquifers.

1.3 Previews studies

Abed Rabbo, A., Scarpa, D., Qannam, Z., Abdul Jaber, Q., and Younger, P., (1999): discussed water quality and chemistry of the springs in the West Bank including part of the springs and dug wells in the study area. The authors conclude the following points: all the springs of the West Bank are usually contaminated with coliform bacteria, and are thus unsuitable for drinking unless disinfected properly. The majority of the springs of the West Bank are suitable for drinking from chemical point of view, as the concentration of the various health hazard parameters, such as nitrate and heavy metals, are within the acceptable limits. According to the WHO guidelines, springs in the southern West Bank have a high nitrate concentration. Examples of these springs are El Balad in Irtas and Hussan and Mar Saba in the Bethlahem district. Springs of Haj Hamid in Arroub, EL Balad in Si'ir and Beit Ummar, Eth Tharwa in Halhul, and Arab in Hebron City have a very high nitrate concentration.

Harmful concentrations of heavy metals were not recorded in any of the springs of the West Bank. Based on SAR and SSP values, water of all the springs of the West Bank is suitable for irrigation except Malih, Feshkha, Mar Saba and El Hemme in Bardala. The most abundant water type in the West Bank is the earth alkaline water with prevailing bicarbonate, while the second dominant water type is the earth alkaline water with increased portion of alkalis and prevailing bicarbonate. The earth alkaline water type with increased portion of alkalis and prevailing chloride is less abundant than the other types above. The alkaline water type with prevailing chloride is the least abundant water type. This difference in water type could be resulted from the mixing with wastewater, or by ascending saline water from deeper aquifer, or by leaching of the aquifer material.

ARIJ (1995): reported the primary environmental issues at Bethlehem area such as: climate, water resources, soil, agriculture, land use, solid waste and wastewater, pollution sources. Some of the climatic characteristics of Bethlahem area are present in this report. Mean annual rainfall from 1961-1990 is 609 mm, mean annual evapotranspiration is about 1400-2600 mm, mean annual temperature is about 17-23, mean annual relative humidity is about 60%, and the sunshine on average is 7-13 hours.

The main dominated soil in the district is Brown and Pale Rendzinas and Terra Rosa. Brown and Pale Rendzinas soil cover an area of about 96.3 km² and distributed in Bethlahem, Beit Jala, and Beit Sahour area. Terra Rosa soil covers an area of about 73 km², and concentrated in the western part of Bethlahem City at the villages of Battir, Wadi Fukin, Hussan, and Nahhalin. ARIJ also considered the water resources in Bethlahem district especially on wells at the eastern basin and on some springs in western side of Bethlahem City.

Amit, et.al., (2002): Interpretation of spring's recession curves. In this study, the author analyzes discharge data from perennial springs in the Jerusalem Mountains. All the springs drain perched carbonate aquifers. Eight of the studied springs discharge from a karst dolomite sequence, whereas one flows out from a fractured, slumped block of chalk. The author focuses on recession curves of those springs to provide data on storage properties and different types of media such as porous, fractured, cracked lithologies and karst. The results show that springs that emerge from chalk formation has a slow flow and lower hydraulic conductivity, whereas springs that emerge from dolomite and limestone formation has a fast flow and high hydraulic conductivity. The results also give information about the volume of water stored in the aquifer above the spring level. Springs with higher storage coefficient have a large volume of water stored above spring level, while springs with lower storage coefficient have a small volume of water stored above the spring level.

Haviv, I., and Asaf, L., (2005): have considered the hydrological system of Wadi Fukin springs. This report contains some climatic and hydrological parameters, such as rainfall, recharge area, and the geological outcrops over Wadi Fukin area. According to this report the Wadi Fukin area lie at 600-700 masl and has a sub-humid Mediterranean climate. The average annual rainfall is approximately the same of the average annual rainfall of Soreq Cave and Jerusalem stations, and equal to about 572 mm in Soreq Cave area and 575 in Jerusalem district during the period (2001-2002). The springs in Wadi Fukin are fed by a local unconfined perched aquifer, and the springs emerge either from the dolo-limestone rocks or from the alluvial formation which covers the Wadi. The dolomite and limestone formations have a high hydraulic conductivity due to the fracture and dissolution conduit. The recharge area is small and consists of approximately 6 km².

Palestinian Water Authority (2002): Sustainable management of the West Bank and Gaza aquifers. This report considered the hydrological parameters (mean annual rainfall, surface runoff, infiltration, and potential evaporation), and physical properties of the western aquifers. The mean annual rainfall of western basin ranges from 600-700 mm, temperature is 17-19 C°, annual mean relative humidity is about 60-65%, potential evaporation is 1400 mm, amount of surface runoff is 231,62 Mm³, and the infiltration is about 23%. This report is also including some physical properties of western aquifers such as hydraulic conductivity, specific yield, and storage coefficient. The hydraulic conductivity of these aquifers range from 0.1-53 m/d and storage coefficient 0.0035 in confining zones up to 0.04 in phreatic areas.

Scarpa, D., (2002) A: Capacity building for a program in water resources management in Gaza and the West Bank. This report considered the geological history of the West Bank, general geological outcrops, Stratigraphy of West Bank, ground water flow, and mountain aquifer in West Bank. The author studied the hydrogeological characteristics of the three general basins in the West Bank, such as the type of formation existed in each basin, recharge area, general geological cross section over these basin, and ground water flow direction. The stratigraphy and thickness of formation was taken from the well log over each basin.

Scarpa, D. (2002) B: Concentrated on the quality and sustainability of the water resources available to Arab villages to the west of the divide in the southern West Bank, considered 75 springs in Hebron and Bethlahem area. The result of analysis shows that most of springs are infected with coliform bacteria and is not suitable for drinking. The springs placed into three groups according to their water chemistry. The discharge from most of the springs is of calcium carbonate water with prevailing bicarbonate, indicating recharge water reacting with the limestone rocks. Characteristic of this type are the springs of Firah in the Wadi Deir Iqtah near Idna, the municipal spring (Balad) and Umm el Deek in Wadi Fukin, Namous in Hussan, Jami in Battir and two of the springs north of Dura, Kanar West and Kanar East. A smaller group of springs discharges earth alkaline water with increased portions of alkalies and prevailing bicarbonate. These include three springs to the west of Beit Ula; Al Masna, Ahmad Abdullah and Issaq al Adam. Howooz in Taffuh, Musallam, a shallow well to the south-west of Tarqumiya, the municipal spring (Balad) in the grounds of the clinic at Idna and Qais in Abda. One of the three springs sampled from Wadi Fukin, Al Fawwar, is also included in this group. A third group is classified as earth alkaline water with increased portions of alkalies and prevailing chloride and sulphate. This group includes two springs from Beit Ula; Jamil al Amlah and Fawzi al Adam, two from Dura; Nabil Sharif and Saqiya, as well as Al Bus from Idna and Ali Taha from Tarqumiya. Their location, close to arable farming, accounts for the sulphates, derived from agricultural applications.

Tagar, Z., Keinan, T., Bromberg, G., (2004): This report describes one of the most severe environmental problems threatening Palestinians and Israelis: large-scale pollution of freshwater resources. This report details the geographical characteristics of the Mountain Aquifer, points at major sources of pollution from sewage, describes the different solutions that have been proposed and attempts to identify factors that prevent the implementation of sewage solutions. The results show that there are large quantities of untreated sewage run on the surface of the Mountain Aquifer and percolate into the ground and threaten the continued utilization of vital water resources. Pollution sources are both Palestinian and Israeli, the threat to future water supplies is undisputed and evidence shows that groundwater in some locations has already been polluted.

As shown from the previews studies it's clear that, one or two springs from the study area were considered, while the others were not. A previews study has generally searched the hydrogeology of the West Bank, but it didn't include the study area. This easily shows that study area will add much on the hydrogeology and hydrochemistry of the water resources in the study area.

7.2 Recommendations

- It is recommended to replace conventional septic systems by the construction of wastewater treatment systems for protection springs water from contamination.
- It is recommended that specific watershed management plans should be established in the area to protecting aquifers recharge area, and ensuring water quality protection from pollution.
- Raising public awareness and establishing legislation to protect the quality of groundwater.
- It is recommended to avoid the planned urban development along recharge area of springs.
- It is necessary to monitor water volume and quality over long period to establish baseline information needed for planning for the future of spring in the study area, and its relation to human usage.
- Reduce contamination of the recharge areas from agricultural chemicals and disposal of human and livestock sewage.
- The amounts and types of fertilizer used in the watershed of springs should be limited and regulated through a combination of public education and targeted ordinances.
- It is recommended to applied geophysical technique (electrical resistivity surveying) to obtain subsurface information such as (water level, permeability), and compared with result from theoretical methods.