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Retraction

Retracted: Intelligent Oil Production Stratified Water Injection Technology

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This article has been retracted by Hindawi following an investigation undertaken by the publisher [1]. This investigation has uncovered evidence of one or more of the following indicators of systematic manipulation of the publication process:

(1) Discrepancies in scope
(2) Discrepancies in the description of the research reported
(3) Discrepancies between the availability of data and the research described
(4) Inappropriate citations
(5) Incoherent, meaningless and/or irrelevant content included in the article
(6) Peer-review manipulation

The presence of these indicators undermines our confidence in the integrity of the article's content and we cannot, therefore, vouch for its reliability. Please note that this notice is intended solely to alert readers that the content of this article is unreliable. We have not investigated whether authors were aware of or involved in the systematic manipulation of the publication process.

Wiley and Hindawi regrets that the usual quality checks did not identify these issues before publication and have since put additional measures in place to safeguard research integrity.

We wish to credit our own Research Integrity and Research Publishing teams and anonymous and named external researchers and research integrity experts for contributing to this investigation.

The corresponding author, as the representative of all authors, has been given the opportunity to register their agreement or disagreement to this retraction. We have kept a record of any response received.

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[1] H. Cheng, D. Yang, C. Lu, Q. Qin, and D. Cadasse, "Intelligent Oil Production Stratified Water Injection Technology," *Wireless Communications and Mobile Computing*, vol. 2022, Article ID 3954446, 7 pages, 2022.

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Research Article

Intelligent Oil Production Stratified Water Injection Technology

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As the driving energy to deal with the decrease of interlayer pressure caused by continuous oil production, the layered water injection technology has the characteristics of inhibiting the decrease of oil production and slowing down the increase of oil/gas ratio. In engineering, water injection technology is often used to improve the properties of crude oil, such as excessive viscosity, weak liquidity, and depleted storage, to avoid the formation of dead oil. Injecting appropriate amount of water into different production horizons can effectively maintain the formation water injection pressure, improve the sustainable development speed of the oilfield, ensure the oil production and effectively control the production cost. It is of great value to petroleum engineering and has been widely concerned by the industrial and academic circles at home and abroad. With the continuous development of oilfields over the years, most oilfields have become high-water-cut oilfields. Through the existing layered water injection technology, there are defects such as high labor cost, low operating efficiency, and long commissioning cycle. The ratio of water injection cost to constant increase gradually decreases, and the technical shortcomings become more and more obvious, which is difficult to meet production needs. It is urgent to study and optimize water injection technology scheme to meet oilfield production and technology iteration. In recent years, electronic technology, communication technology, automatic control technology, and other advanced production technology applied to geological exploration, logging technology fields such as engineering, oilfield development is towards integration and intelligent direction, which makes the advanced control and real-time communication intelligent power precision, and the layered water injection technology is possible. This paper summarizes the development history and status quo of oil recovery stratified water injection technology at home and abroad and points out that there are technical bottlenecks and development limitations in the development of water injection technology at present. Focusing on the current hot spots of intelligent oil recovery stratified water injection technology, the advantages and disadvantages of various intelligent water injection technology are compared and analyzed. It provides a certain theoretical reference value for the theoretical research and engineering application of intelligent stratified water injection technology to the equipment design and production of oilfield production and oil recovery technology research institutes and technology and equipment manufacturers.

1. Introduction

Oil and gas resources are important primary energy resources. With the continuous development of national economy and the increasingly high requirements of people's life quality, the pressure of national energy security is unprecedented. In fact, the amount of fossil fuels such as oil and coal that can be extracted and the amount of time that can be extracted are declining at an accelerating rate, in dramatic contrast to the increasing needs of society [1–4]. The implementation of the "energy conservation and emission reduction" policy and "carbon neutral" and the aim of "carbon peak" are expected to use new energy to gradually replace the traditional energy, but in a short period of time, oil and other fossil fuels still are the main energy pillar of the national development, even into energy system center is given priority to with new energy, oil and gas resources will be continued in the form of combat readiness resources. Therefore, the research on automation and intelligence of oil and gas exploitation technology is of great guarantee significance and economic value for national development and industrial progress. The continuous exploitation of oil fields for many years makes the properties of underground crude oil change, such as viscosity increase, exhaustion, and even the oilfield become unrecoverable dead oil due to lack of displacement energy [5–9]. In industry, water injection technology is often used to stabilize the pressure difference between oil zones and improve oil recovery efficiency. In order to effectively improve the original recovery, oil companies at home and abroad often adopt layered water injection technology, the principle of which is to take advantage of the oil and water density difference, water into the rock to drive crude oil, and convenient collection. Compared with the mixed water injection technology, the layered water injection technology can effectively avoid the problem of weak oil displacement effect and affecting oil recovery rate caused by uneven water inflow in some well sections. Table 1 shows the data of injection wells in a domestic oil field. According to the data in the table, the ratio of water injection technology and equipment in domestic oilfield exploitation is relatively high.

China's rapid economic development over the years, the demand for oil and gas resources, oil field production scale, and supporting technology are relatively perfect; the number of oil wells and water content is constantly improving; stratified water injection technology has also put forward higher performance requirements. Since the 1950s, waterflood oil recovery has been gradually understood by domestic industry and academia [10–15]. After years of development, an independent waterflood oil recovery technology system has been formed. Table 2 shows the development process of waterflood technology.

The start time of water injection technology in China is similar to that in foreign countries. The first water injection technology was implemented in MN27 well at the edge of L layer L in Laojunmiao Oilfield in Yumen in 1954. The early general water injection and mixed water injection have gradually developed to today's layered water injection. After years of water injection technology updating and iteration, the layered water injection technology adopted by Dagang Oilfield, Tarim Oilfield and Shengli Oilfield has been in the international leading position in China, which has promoted the continuous development of you water injection technology. [16–20].

However, after years of mining, the water content of China's oil fields has entered the middle and late stage, and the continuous injection of oil and water and natural underground water will cause rust, corrosion, and wear of underground mining and testing equipment, resulting in large deformation, cracks, and defects of equipment, and even affect the normal operation of oilfield equipment. This shows that the extensive water injection technology can only achieve the simple function of water flooding oil, it will cause great trouble to the long-term reliable operation of downhole equipment, and it is difficult to meet the needs of modern oilfield production. In addition, due to the lack of data monitoring and information feedback, it is difficult for the staff to obtain specific downhole data, so it is impossible to achieve fine water injection, resulting in a large waste of resources and poor improvement of oil recovery. In view of this, domestic and foreign petroleum enterprises, scientific research institutes, industry colleges, and universities rely on modern information, automatic integration, and other advanced mature technology, centering on the construction of digital oilfield and intelligent oilfield, explore to meet the requirements of improving oil recovery rate, environmental friendly, resource-intensive, and visual adjustable intelligent oil recovery stratification technology research [21–24].

In view of the problems existing in the existing water injection technology, this paper compares and analyzes the characteristics and defects of the existing water injection technology, studies the frontier hot spots and development trends of the existing intelligent oil recovery stratification water injection technology at home and abroad, and explores the implementation path and application scope of intelligent oil recovery stratification technology. It provides theoretical research and data sorting for the development of intelligent oil recovery stratified water injection technology and intelligent oilfield construction and helps the development of greener and more intensive new stratified water injection technology.

2. Methods and Materials

2.1. Characteristics and Defects of Existing Water Injection Process. After years of development, water injection technology now has a perfect technical system and targeted application fields. In some high water-cut oilfields, the injection-production ratio relationship is complex, the degree of oil-water flooding perfusion subdivision is low, and the testing period of strata stratification is long, so water quality is difficult to monitor, and secondary pollution is easy to occur frequently. Table 3 shows the characteristics and defects of the existing water injection process.

China has a perfect production system and experimental conditions, the stratified water injection has made remarkable achievements, and in each stage and all kinds of working conditions, there are corresponding complete sets of technical support. However, domestic intelligent well technology is still in its infancy, and the testing efficiency needs to be improved. At present, real-time monitoring of downhole conditions and precise movement commands cannot be realized. In view of the current industry development trend, the intelligent production of zONAL water injection technology should include at least two points: (1) ensure high accuracy and dynamic real-time detection of downhole data; (2) effectively control the water injection rate, pressure, and water volume of each rock layer to achieve complete control of water injection points of each rock layer. At present, the more advanced intelligent water injection technology is still mastered in foreign petroleum enterprises, which can realize more precise current continuous control and effectively improve the accuracy and reliability of water injection. In particular, oil field dynamics, a joint venture

Table 1: Data of injection wells in a domestic oil field.

The serial number	Category	Quantity/unit	The serial number	Category	Quantity/unit
1	Number of developed fields	50	7	Well open rate	66%
2	Number of waterflood fields	42	8	Water injection allocation	$32 * 10^4 m^3/d$
3	Water driven geological reserves	20 * 100 m tonnes	9	Daily volume	$46.2 * 10^4 m^3/d$
4	Total number of injection wells	6400 mouth	10	Scheme separate injection wells	2743
5	Water injection allocation	$58.3 * 10^4 m^3/d$	11	Quantity of injection allocation	$28 * 10^4 m^3/d$
6	Open well number	4230 mouth	12	/	/

Table 2: Development history of water injection technology at home and abroad.

The serial number	Time	Unit	Name of specific technology
1	Mid-20th century	North Sea oil	Waterflooding
2	In the 1960s	Acro-company	Plc water injection control pump
3	The mid-1970s	The United States	W type multistage high pressure centrifugal water injection pump
4	The early 1980s	The United States	Horizontal water injection pump
5	Late 1890s	Royal Dutch Shell	Intelligent well completion technology (IWCT)
6	Late 1980s	Lunfkin company	Dos water injection monitoring system
7	Early century	/	Based on pulse water flooding technology
8	Late 1980s	British petroleum	Automatic water injection technology

between Royal Dutch Shell and Hareton, has mastered hardware products such as hydraulic control valves and stepless control valves, as well as data services such as downhole data acquisition and flow management.

2.2. Calculation Method of Injection-Production Ratio. Injection-production ratio is an index to characterize the balance between water injection and oil production in oilfield development and reflects the internal relationship between water injection, oil production, and rock formation pressure. Therefore, the study of injection-production ratio is one of the core of intelligent oil production stratification technology. The rational model of injection-production ratio is an important prerequisite for determining the optimal injection-production ratio and also the theoretical basis for ensuring the proper pressure difference and water content of oil field. This section will compare and discuss common injection-production ratio calculation methods.

Empirical method is the method used in early oilfield development, and its principle is based on the detailed analysis of the data recorded in the early oilfield production, especially the "water-production" balance, pressure difference stability, oilfield water content, and other information, and then according to the engineering experience to judge and determine the injection-production ratio. The form of empirical method often depends on the accumulation of long-term working experience of technical personnel and has poor universality. It is difficult to find the appropriate parameters for the technical personnel who contact with it for the first time or the oil field that is exploited for the first time, so it can only be judged according to previous experience and continuously modified in continuous production.

Multiple regression method is based on multiple factor control models such as pressure difference between water injection and oil recovery, oil recovery rate, and water content of oil and gas in rock strata. This model is suitable for predicting the optimal "water injection and oil recovery" ratio in different stages of fracture development in rock strata. Combined with actual production data, the results have high reliability. Multisource regression method is a complex model with multiple factors, including oil volume factor, oil compressibility, oil density, optimal oil production rate, reasonable bottomhole flow pressure, and other factors. It relies on the actual operation data of multiple equipment in the oilfield and has a good overall effect. However, due to the excessive influence of empirical coefficient, the accuracy needs to be improved.

Back propagation neural network (BP) is an error back propagation algorithm discovered by David Runelhart and David Parker in the 1980s on the basis of a single-layer perceptual network (M-P model). BP is a nonlinear optimization method which takes the network error square as the objective function and uses the gradient descent method to optimize the objective function to minimize the error. Figure 1 shows the structure of a three-layer BP neural network (the number of BP neural network layers ≥ 3). The multilayer complex network structure of BP neural network is suitable for large-scale data analysis and describes complex mapping relations through the action of multiple neurons, so multiple regression method and empirical method have better applicability.

Table 3: Characteristics and defects of existing water injection process.

The serial number	Process name	Process characteristics	Defects
1	Eccentric integration	No card distance limit	Limited efficiency gains
2	Constant flow water distribution	Effective balance of nozzle pressure	Only suitable for large displacement and low precision water injection
3	Storage stratified water self-regulation	The water quantity is set on the ground and executed by downhole equipment	High construction cost and long recovery cycle
4	Two small one	Effectively shorten the clip distance	Low efficiency
5	Concentric integration	Effective injection allocation of multistage	Easy to affect the plug
6	Bridge eccentric	Record single formation data	Extensive water injection
7	Side of the adjustable linkage	Electric control	High construction cost

However, with the increase of neural network layers, the structure becomes more complex, and the cost of model training will also increase. Therefore, the selection of appropriate network layers, training times, and error accuracy is the key to achieve the optimal injection-production ratio.

In addition, waterflooding characteristic curve method, material balance method, and other calculation methods are often used in oilfield production. In order to clarify the applicability of various methods, the advantages and disadvantages of various methods are investigated and sorted out as shown in Table 4.

2.3. High/Low Permeability Reservoir Parameters. In order to realize accurate water injection in different strata (high permeability reservoir and low permeability reservoir) and ensure balanced advance of water drive front, the intelligent oil recovery stratification technology is important to understand the characteristic parameters of low permeability reservoir. In order to facilitate the classification of permeable reservoir types and grades, the planning standards of SY/T 6169-2021 Oil and Gas Industry Standard for Reservoir Classification are as follows:

High permeability $\geq 500 \times 10^{-3}$um^2.

50×10^{-3}um^2 $\leq$ the permeability $\leq 500 \times 10^{-3}$um^2.

10×10^{-3}um^2 $\leq$ general low permeability $\leq 50 \times 10^{-3}$um^2
.

1×10^{-3}um^2 $\leq$ special permeability $\leq 10 \times 10^{-3}$um^2.

Ultralow permeability $\leq 1 \times 10^{-3}$um^2.

50×10^{-3}um^2 $\leq$ the permeability $\leq 500 \times 10^{-3}$um^2.

Low permeability reservoir is characterized by low porosity and permeability and poor crude oil quality. In the process of waterflooding development, various parameters of the formation are constantly changing. With the change of working conditions, new situations may occur. Therefore, even in the same permeable layer in different water injection period, the size distribution of porosity will be different. The average porosity increases from low water hydrator to high water hydrator, but its peak value decreases correspondingly. This is because the injection of oil and water has a cleaning effect on the rock layer, which leads to the loss of fine particles in the rock layer and the increase of particles in the rock layer, resulting in better porosity and permeability of the rock layer.

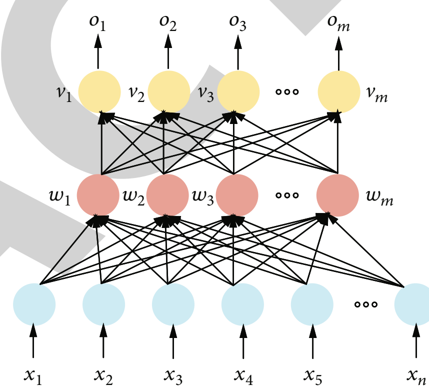

Figure 1: Three-layer BP neural network.

At the beginning of water injection, the oil content of each reservoir is much greater than that of water, presenting a pattern of "more oil and less water." Oil is in a connected state, while water is in a dispersed state, and each reservoir is oil-wet. With the increase of oil exploitation and water injection, the oil and water content of each reservoir gradually changes, water slowly connects into a network, and oil tends to disperse, showing a pattern of "oil reducing water increasing," and each reservoir gradually changes from "water-wet" to "oil-wet." The current recognized standard in China is SY/T 6285-2011 Oil and Gas Reservoir Evaluation Method, which stipulates: porosity > 20%, permeability greater than 100×10^{-3} um^2 is considered as a good reservoir. 20% > porosity > 12% and 100×10^{-3}um^2 > permeability > 1×10^{-3} um^2 are the second class reservoirs, and the evaluation is medium. 12% > porosity > 7% and 1×10^{-3} um^2 > permeability > 0.1×10^{-3} um^2 are the three types of reservoirs, and the evaluation is poor. If it is lower than the three criteria, it is considered as nonreservoir.

3. Results

The development history of waterflood recovery at home and abroad is reviewed above, and various existing domestic stratified waterflood technologies are compared and analyzed. At

Table 4: Characteristics of various injection-production ratios.

The serial number	Method category	The production parameters	Characteristics	Defects
1	Empirical method	Technical personnel experience	It is suitable for experienced technicians or oil fields with mining experience	No evidence, theoretical support
2	Multiple regression method	Water injection, oil production, water-oil ratio, rock pressure, and oil recovery rate	The structure of the model is complex according to many factors	It is highly dependent on parameters and is not applicable to early developed oil fields
3	BP neural network	Water injection and oil production	Capable of fast fitting complex mappings, suitable for multivariable models	Modeling is complicated, especially the number of network layers and training times

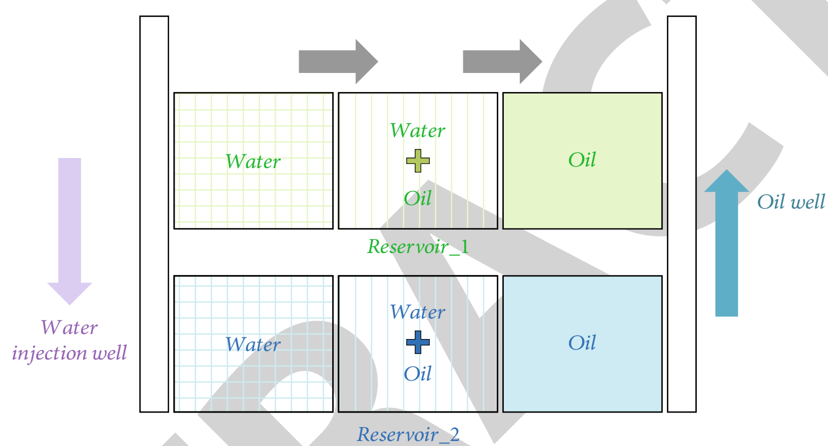

Figure 2: Unidirectional flooding model.

the same time, the influences of injection-production ratio and reservoir parameters of high/low permeability reservoirs are studied. The model is shown in Figure 2 for single-phase water flooding, the figure shows oil displacement by water injection into different layers, when the rock water content reaches to a certain extent, the reservoir forming inside the "water" "water oil mixed area" "region," and with the increase of water injection, crude oil and injected water are extracted to the surface by pumping unit.

Intelligent production of stratified water injection technology is a new reservoir production technology and is also an important construction content of green oilfield and intelligent oilfield. The technology uses sensors as detection devices to obtain downhole temperature, pressure, humidity, water content ratio, and other data, which are transmitted to the control center through communication equipment, and then the water injection volume and water injection rate of each reservoir are obtained by integrating historical parameters, injection-production ratio model, and reservoir parameters calculation in the computer. In this way, intelligent oil production closed loop is formed through modern detection and control technology to achieve flexible and controllable injection water. In addition, modern data processing model is used to fully mine data and accumulate more reliable production materials for later oilfield construction.

Figure 3 shows the layered water injection pressure model. It can be seen from the figure that the oilfield strata contain multiple reservoirs with different permeability. Independent testing equipment and adjustable water injection valves are installed in each reservoir to detect downhole data and send water injection instructions. Its intelligent processing ideas are as follows: (1) collect data; (2) data preprocessing and optimization analysis; (3) combine the existing model, measured parameters, and historical data to determine the current situation; (4) whether it meets the production requirements, turn to (5) if it meets the requirements, and turn to (6) if it does not; (5) water injection volume and rate shall be maintained, and corresponding data shall be recorded; (6) increase/decrease water injection volume, water injection rate, and other parameters. Through the above process, intelligent judgment can be completed. The current communication cable transmission rate can reach several megabits per second, and the processor speed can reach up to 150 M (TI DSP series products), so the model adjustment time scale can be second unit, with high accuracy and real-time.

In the development of intelligent stratified water injection technology in the future, the economy and technology of oilfield exploitation should be integrated to establish the joint optimization model of "economy-technology-

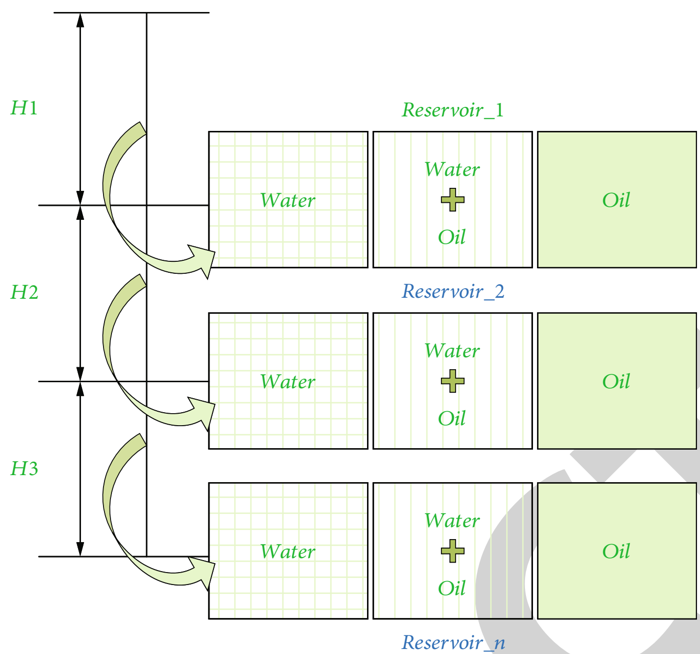

Figure 3: Layered water injection model.

reliability," which lays a theoretical foundation for the development of more intelligent and economic oil recovery technology and contributes to the construction of intelligent oilfield.

4. Conclusions

(1) In this paper, the intelligent stratified oil recovery technology in petroleum engineering is taken as the research object. The development history of various water injection technologies at home and abroad since the middle of the 20th century is summarized. The existing stratified water injection technologies in China, represented by eccentric integration and constant flow water distribution, are comparatively studied

(2) In view of the shortcomings of water injection and oil production through outlet, an intelligent layered water injection technology represented by multiple regression method and BP neural network is proposed. The injection production ratio and related water injection parameters are automatically adjusted for reservoirs with different percolation capacity, which can provide reference for oil production units and scientific research institutes

(3) As a common way to increase production and energy in oilfield production, zonal water injection recovery technology has developed rapidly over the years. With the further improvement of electronic information technology and computer computing ability, intelligent technology has gradually entered this industrial field. As an important means of life and production, oil and gas resources have always been valued by scholars at home and abroad because of their special significance and economic value in green, efficient, and sustainable exploitation. In the next step, more research will be carried out on the industrial practical application of intelligent production stratification technology

Data Availability

The figures and tables used to support the findings of this study are included in the article.

Conflicts of Interest

The authors declare that they have no conflicts of interest.

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