Desalination and Water Treatment
www.deswater.com
doi: 10.1080/19443994.2013.829596

52 (2014) 1183–1192
January

Taylor & Francis
Taylor & Francis Group

Study of the comprehensive landscaping treatment technique of saline–alkali land in Daqing based on the network of the grading of trapezoidal terrace ditches

Bin-xia Xue[a,]*, Zhi-qing Zhao[a], Li Wei[b], Tong-yu Li[a], Xiao-fei Kang[c]

[a]*School of Architecture, Harbin Institute of Technology, Harbin 150006, China*
Tel. +86 451 86283798; Fax: +86 451 86281048; email: binxia68@126.com
[b]*State Key Laboratory of Urban Water Resource and Environment, Harbin Institute of Technology, Harbin 150090, China*
[c]*Urban Planning and Design Institute, Harbin Institute of Technology, Harbin 150006, China*

Received 19 March 2013; Accepted 1 April 2013

ABSTRACT

Salinization of the soil in Daqing in China is the main result of its geographical structure and climate condition. Oil exploration and overgrazing anthropogenic factors lead to the concentrated distribution in the form of plague, which threatens the inhabitation comfort and sustainable land use of the city environment as the oil operation and grazing zone expand. The treatment and subsequent development of saline/alkali land in Daqing are extremely crucial to curtail environmental desertification and promote the development of industries during the urbanization. This study compares the traditional physical, chemical, and biological technologies for the improvement of salinization land to establish the combined method of technology optimization. Considering the water conservancy as the guidance, the aim is to present the stable long- and short-term combined technological method of biological improvement from the view of eco-restoration and industrial renovation, supported by the physical and chemical improvement. The technology of network of the grading of trapezoidal terrace ditches, which combines the trapezoidal terrace with landscape using natural sedimentation, is proposed. The indoor terrace elution experiment indicates that the salinity reduced by 52%, alkalinity 50, and 50% for oily substances during 48 h; this technology is combined with comprehensive utilization of the waste, collaborative repair of the microorganisms and plants to offer new views and theoretical support for the protection and development of the saline/alkali land in Daqing area.

Keywords: Trapezoidal terrace; Grading ditches; Saline/alkali land; Landscaping; Comprehensive treatment technologies

1. Introduction

Saline soil and alkali soil types are collectively called saline/alkali land, with a content of soil of 0.1% or the pH of the soil is greater than 8.0 and the exchangeable sodium percentage (ESP) exceeds 5% [1]. Worldwide, more than 800 million hectares of soils are salt-affected, with a range of soils defined as saline, acidic–saline, alkaline–saline, acidic saline–sodic,

*Corresponding author.

Presented at the Fifth Annual International Conference on "Challenges in Environmental Science & Engineering—CESE 2012" Melbourne, Australia, 9–13 September 2012

saline–sodic, alkaline saline–sodic, sodic, acidic–sodic, and alkaline–sodic [2]. Saline/alkali land is an issue faced by many countries and areas, particularly arid and semiarid areas. Its treatment involves soil improvement and natural or agricultural eco-systems and also has an influence on the health of the inhabitants and urban development. Saline areas are increasing in China, mainly throughout the inland areas of the northeast, north, and northwest and the region north of the Yangtze River. Due to the urbanization and industrialization processes of the past 50 years, the saline/alkali area is growing, challenging both agricultural production and the urban environment. The Songnen Plain is one of the three areas with characterized by saline/alkali soil and is one of the most seriously salinized lands. The area of saline/alkali land had increased from 401.48×10^3 ha in 1954 to $1\,097.45 \times 10^3$ ha in 2005, while the ratio of light, moderate, and serious salinized land areas changed from 6.72:2.92:1.00 to 1.25:1.06:1.00 in the study period. [3]. And among them, Daqing City, comprising an oilfield, is a severe example of these areas. The wetland and grasslands of a century ago have become blocks of alkali lands due to the characteristics of the geological structure and oil development over the decades. The second national soil survey data indicate that the area of salinization is 2.87×10^5 hm^2 in Daqing, accounting for 59.4% of the total area of this region. The arable land is approximately 21×10^3 hm^2, accounting for 20.9% of the total arable land. The remaining land area is predominantly used for animal husbandry [4].

The saline sodic soil, dominated by $NaHCO_3$ and Na_2CO_3 in its salinity constitution, bulges, disperses and gets muddy when it is wet and compacts and hardens when it is dry, resulting in poor ventilation and permeability [5]. The primary problems associated with salinity and sodicity are reductions in plant productivity due to water stress caused by the increased osmotic potential and changes in soil physical properties (dispersion with a resultant reduction in permeability) when salt or sodium concentrations in soils become too high [6]. The plants are limited, and their growth is inhibited by the negative physical and chemical properties [7], ultimately leading to desertification and subsequent serious environmental problems. The area of saline land continues to expand because of the accelerating soil and chemical pollution, excessive human activities and production, which severely degrade the soil. However, as the economy develops and the population grows in the Daqing area, the demand for land development and utilization is increasing annually due to urban construction and agriculture and forestry land uses. The approaches used to identify creative and suitable treatment methods based on the extensive research of the site conditions and the mechanisms involved in their formation play important roles in establishing the balance of the economy and improving the living environment with respect to multiple values while still maintaining urban development.

2. Causes and characteristics of the saline/alkali land in Daqing

2.1. Causes and characteristics

Located in the western region of Heilongjiang Province and in the middle (E 124°13′–125°16′, N 45°46′-47°02′) of the Songnen Plain, Daqing belongs to the northeastern subhumid, semiarid plain-meadow saline district [1], one of the eight salinization lands in China. The terrain is flat and lies in the continental monsoon climate zone of the north temperature zone, which is subjected to the cold climate of the Mongolian inland and the warm current monsoon from the ocean. The region is cold and snowy in the winter and windy in the spring and autumn with annual average temperature of 2–6°C [8]. Saline land is the result of both natural and anthropogenic factors. The natural condition is described with typical continental climate characteristics [5]. The monsoon climate changes in the winter and summer, with large, obvious temperature differences, and the four seasons are distinct. The annual temperature is 4.2°C, and it is windy in the spring and autumn, with nearly 30 days during which the wind exceeds 6 wind scales. The annual rainfall is 427.5 mm, the majority of which occurs from June to September and is affected by the monsoon atmospheric circulation, far greater than the annual average rainfall [4]. Under the higher ratio of evaporation and rainfall, the soluble salts in the soil and underground water accumulate on the surface with the rising water current. The content of the soil in the surface is approximately 0.3%, with a higher pH that is attributable to bicarbonate and carbonate, followed by sulfate; chloride is present in the lowest concentration. In comparison, cations account for approximately 70% when the pH exceeds 9 [8]. The temperature rises quickly in the spring with the stronger winds, leading to rapid evaporation and the phenomenon known as the salt accumulation period. In comparison, the summer represents a salt desalinization period due to the significant rainfall, which only occurs from June to August due to the short summer. The soil will freeze in the winter, and temperature and humidity gradient differences will be generated between the frozen soil layer and the moisture layer during the freezing process, causing the thermal capillary movement of the moisture. The soil water underneath the frozen layer and the underground water will concentrate in the frozen layer to form a hidden layer of salt accumulation. In the spring, the soil begins to thaw, and the frozen layer will also thaw from the top down to the lower layers. The melted water migrates and evaporates upward, causing the salt to accumulate on the surface soil, and thus form the re-accumulation of the salt in the spring.

The main reasons for this salinization include improper irrigation, oil exploitation, and vegetation destruction. The unsustainable economic activities and utilization also exacerbate the extent of the salinized land. The original surface vegetation and soil structure are devastated by the destruction of the grasslands, overgrazing and oil operations, raising the soluble salt contained in the oil and underground through the soil porosity and causing it to accumulate on the soil surface. The irrigation with a considerable amount of water in traditional agriculture is similar to flooding, which easily causes secondary salinization. The oil exploitation and deforestation both destroys the vegetation and upsets the balance between the soil and underground water level. The soil is exposed when trees are chopped down; water evaporation is decreased, and the underground water level rises. In addition, the amount of rainfall entering the soil will increase, raising the underground water level and eventually leading to soil salinization [9]. In particular, within the vicinity of oil wells, pipelines, and roads, a large amount of grassland is salinized and covered by alkali spots.

2.2. The principal characteristics of the saline-alkali land

The salinization in Daqing is mainly produced from its own geographical and climatic conditions. The distribution of saline areas is spotty and concentrated and is extended under the influence of the human factor, including oil exploitation and overgrazing. The degree of saline/alkali is described as a strong seasonal fluctuation and guided by the underground water level and reinjection water from the oil industry. Its formation mechanism is more complex. Daqing, therefore, is featured as the intersection of multiple factors, with the alternation of salinity and alkalinity being persistent, and the area is further polluted by the oil industry. The content of salt is higher with a higher oil content (the percentage $> 2\%$). The saline soil has three categories based on the pH, soluble salt, and organic matter: light, medium, and serious. Different methods have been used to improve the physical and chemical properties of the soil; correspondingly, plants that are resistant to drought and salinity are planted [10]. Relying on the climate changes regarding drought and flood and the clay properties of the soil, during the processes of flooding or wind disaster, the farmland and wasteland soils will be exposed to the air due to the higher geographical position or the thin water layer. The temperature of the ground is higher with significant evaporation, resulting in the drawing up of the soil moisture, which raises the salt and forms a salt spot. Additionally, the low parts of the farmland contain the salt in the soil and irrigation water, resulting in the accumulation of salt spots in the low-lying areas. Due to the flooding, the clay layer can be found in the low-lying areas, and it is flaky and tight, with a 5 cm thickness. Water has difficulty infiltrating the clay, and the salt accumulates in the clay layer and will move to the surface soil due to the strong evaporation process to form small salt spots. In addition, the salt accumulates in the soil around plant residues, forming other small salt spots.

The special geographical position, hydrogeographical factors, climate, and production patterns promote the occurrence and evolution of the salinization in the Daqing area. The terrain is flat, and the geography is dominated by closed or slow-flow areas of the surface water. Therefore, the water in the considerable number of rivers and their branches and the surface water generated by the increased rainwater during the summer are unable to be discharged outside of the region through the rivers or underground runoff in a timely manner. In the river–lake floodplain and local low-lying areas, the water balance is regulated by evaporation, and the salt contained in the water accumulates gradually, increasing the mineralization of the underground water and surface water and, thus, increasing the salinization.

The characteristics of the geographical environment and industrial structure of the area, persistence and expansion greatly increase the difficulties of dealing with the salinization thoroughly.

3. Current conditions of saline/alkali land treatments and exploration of its new technologies

Saline/alkali soil is known to be costly to remediate. Thus, every country performs steps to improve the treatment of the soil and prevent the soil from secondary salinization. In recent years, the main treatment and management measures have included water conservancy, agricultural technology, and biological and chemical improvement [11]. Due to the characteristics of saline/alkali soil, the phenomena of double salts, soil hardening and basification occur frequently. Therefore, techniques and application scope are decided reasonably according to the actual situation to conduct a comprehensive treatment and management measures by combining various techniques.

3.1. Problems with traditional treatment measures

The different techniques and measures of improving saline/alkali soil, such as water conservation, agricultural technology, biological and chemical improvement measures, show quite different effects and have resulted in an improvement over the previously utilized treatment processes [12]. However, from the perspectives of the degree of improvement, desalination efficacy, and scope of use, the desalinization of soil by engineering drainage has been identified as an important technical measure. The traditional treatment and management measures for saline/alkali soil focus on the usage of irrigation-drainage systems, such as storage fresh water to suppress the upward migrating movement of the salt, irrigation desalination and the draining of the alkali water and controlling the ground water level below the critical depth; Thus, such an irrigation-drainage system would help with achieving the goal of soil desalination and preventing salinization [13,14]. Moreover, such efforts would improve the breathability and fertility of the soil by chemical methods, such as the addition of coal desulfurization waste, industrial waste acid, peat and gypsum, and soil conditioners. As eco-ideology has strengthened, it has become increasing popular to improve saline/alkali soil using vegetation and microorganisms. Furthermore, these different techniques have their own pros and cons for solving the problem of soil salinization. For instance, the irrigation-drainage measure has disadvantages, such as large working quantities and high investment, operating and labor costs. Additionally, desalinization drainage has the disadvantage of water waste, which removes a large amount of useful mineral elements, resulting in soil depletion and also pollutes the downstream water. In addition, although the physical and chemical improvement measures lay more stress on the engineering measures focused on improvements to the soil and environment and the creation of appropriate growing conditions for vegetation that could obtain effects within a short time, these measures cost a great. Moreover, once these measures are ceased, the salinization would resume immediately, such that the improvement effects would not last long [15]. At present, selecting and planting saline-tolerant plants has been universally recognized as an economic, durable, and effective method of improving saline/alkali soils [16]. Nevertheless, the disadvantage of the biological improvement method is its slow efficiency, and it would not fully take advantage of the saline/alkali soil because of the one-sided focus on seeding without the development of livestock farming [17].

In general, the treatment and management of saline/alkali soil is a complex and systematic project involving various factors. Thus, any single measure would have limited effects. Therefore, adopting comprehensive treatment and management measures according to the causes and characteristics of the saline/alkali soil formation and incorporating the various optimized techniques to realize the sustainable utilization of saline/alkali soils is quite rational.

3.2. Comprehensive treatment methods

A common characteristic of saline/alkali soil formation is the accumulation of salinity from the lower to the upper layers of the soil, and the migration and accumulation of the salinity at the ground surface occur under certain environmental conditions. Therefore, a key procedure of the saline/alkali soil treatment is identified as changing the present environmental conditions to eliminate the causes of soil salt–alkalinization, thus guaranteeing that the soil improvement measures are sustainable. The process of soil salt–alkalinization includes two different soil-forming processes of salinization and alkalization, forming a complex distribution of saline/alkali soil under a composite operation process. Consequently, the saline/alkali soil treatment needs to prevent neutral salts, such as NaCl, $CaCl_2$, Na_2SO_4, and $MgSO_4$, from accumulating on the soil surface or the soil body. In addition, treatments should also avoid the high-alkali tendency of the Na^+ in the soil solution to enter the soil colloids and the deteriorative alkalization process of the soil physical characteristics [3].

The individual factors influencing the formation of saline/alkali soil are the water, salt, vegetation and remaining organic matter, and the topography and weather conditions are identified as external indirect factors. Through water treatment and controlling the water salinity to a concentration suitable for vegetative growth, the foundation of this treatment is to foster the soil fertility [18]. Therefore, the continuous addition of organic matter to the soil is a practical and comprehensive improvement measure to alter the soil structure.

4. Research of landscaping treatment technique of saline/alkali land based on the network of the grading of trapezoidal terrace ditches

4.1. Comprehensive landscaping treatment technique based on trapezoidal terrace

The key of saline/alkali soil treatment is to eliminate the salinity and remove the alkali components. Thus, the water conservancy measure that covers a wide range with rapid effects and an easy operation can be the core technology used to treat the saline/alkali soils in the Daqing area. Given the evolution of the Daqing saline/alkali soil and the impact of the geographic structure and continental climate, the process of salinity accumulation and desalination has an intimate connection with the ground water level. In general, the intensity of the water evaporation from the soil surface varies with the ground water level under certain weather conditions. Thus, the higher the ground water level is, the stronger the evaporation intensity is, and the more quickly salinity accumulates during drought. Nevertheless, during irrigation or flooding, the higher the ground water level is, the higher the water concentration of the soil is, and the smaller the infiltration rate is, resulting in difficulty in the desalination of the soil surface. Due to the long duration of the oil exploration in the Daqing area, the ground water level has decreased gradually in recent years, providing convenient conditions for the comprehensive treatment of the saline-alkali soil using the water conservancy measure as the core technology, with the incorporation of other technologies [7].

First of all, a network for trapezoidal terrace cultivation should be established. The drainage canals and ditches with different depths would be arranged around the cultivated land, and the farmland should be divided into different areas and classes. Thus, a continuous drainage system and landscape pattern is formed by utilizing the differences in the terrain and environmental characteristics and connecting wetlands of various scales throughout the Daqing area. Then, the network of drainage canals and ditches of the trapezium terrace is recommended to perform the alternate farming of rice, corn, and wheat to control the variation in the salinity and alkalinity of the soil by different agricultural technologies and chemical fertilization schemes. The impound process of rice planting and the rainfall during the rainy season would ameliorate the salinity and alkalinity of the soil along the sides of the canals and ditches, which converge together into the wetlands. During this process, there would be a dynamic variation and transformation of the water and salt. The rainfall and irrigation water should wash away the salinity of the soil into the drainage ditches, and the water flow movement should wash away the deep layer of the soil, with a subsequent decrease in the salinity concentration; thus, there would be a pressure salinity effect. However, after the rainfall ceases and the water recedes, the amount and level of water in the drainage ditches would increase, and the salinity and alkalinity concentrations in the drainage canals and ditches would decrease. Because of the different concentration gradients, the salinity of the soil would transfer to the drainage ditches, resulting in the increase in the salinity concentration and some of the salinity accumulating in the ditches [12]. After the long-term evaporation of the water in the drainage ditches, the water level would decrease, and the salinity/alkalinity concentration would increase, followed by the salinity of the ditches being transferred to the deep soil layer (see Figs. 1 and 2). According to the transformation principle of this cyclic process of water and salinity, connecting the drainage ditches with each other would create a relatively integrated drainage system and maintain the appropriate water level to promote the movement of the redundant salinity in the soil. Thus, the redundant salinity would be gradually concentrated into relatively large or deep pond.

To maintain the effectiveness and persistence of the escarpment treatment system, the depth of the drainage ditch should be determined according to the

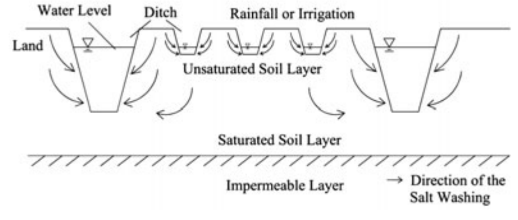

Fig. 1. Illustration of salt mitigating direction when water receded.

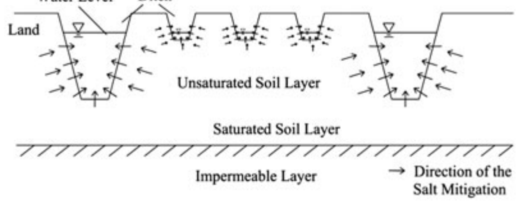

Fig. 2. Illustration of salt mitigating direction after the rain or irrigation.

soil structure and constitution and the critical depth of the ground water in the area and in the impervious underground bed [17]. Commonly, the depth of the main drainage ditch is 1.8 m, the width of the ditch bottom is 1.0 m, and the separation distance is between 400 and 500 m. To avoid the soil resistance of the central area of the escarpment, there should be a secondary ditch every 100 m between each ditch and a water furrow every 9 m in the fields to create a criss-cross system and maximize the effects of the salinity removal. To ensure the robustness of the drainage ditches, saline–alkali-tolerant vegetation, such as Elaeagnus angustifolia and reeds, should be planted at 0.3–1 m from the water line of the ditch slope, and a protection forest in the surrounding area should be established. The running of the drainage ditch needs to pull sands just under the topsoil and extract the alkalinity over time to allow the salinity concentration of the soil reach the minimum that is suitable for the growth of the saline/alkali vegetation, which is a salinity concentration of 0.5–2.0% in the soil layer from 0 to 30 cm [17].

Rice cultivation involves a soil salinity–washing process during the seeding period, steeping field period and original field period, thus allowing the salinity–alkali tolerance index of the soil to satisfy the requirements for the growth of the crop [18]. The continuous salinity removal could avoid the limitation of the season and temperature, and the usage range would also become wider.

Simultaneously, filtering neutralized wells (filtration-proof bells or membrane) are installed at the middle drainage ditches or intersections to avoid the secondary pollution of the salted water to the underground water, other areas or plants (see Figs. 3–7). The daily sludge, industrial waste, and ceramic medium and other acid filler are filled inside to neutralize the precipitated saline water and block the transfer of the soluble salt using the physical and chemical action between them. According to the disaster condition, the salinization, the technology of reverse osmosis and ion exchange can be applied to prevent the salt from penetrating, avoiding the transfer of saline/alkali disaster to other wetlands and therefore causing the secondary environmental pollution. In practice, the separation distance, depth and gradient of the drainage ditches should be determined according to the onsite situation, and different parameters and the salinity-washing type need to be determined empirically to obtain the most optimized treatment effects.

The existing methods to clean saline/alkali lands are costly and are intended to utilize the existing

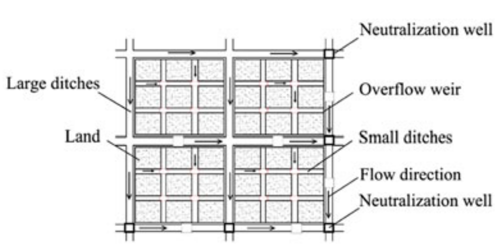

Fig. 3. Layout Ⅰ trapezoidal terrace land: Setup of neutralization well at the intersection of the ditches.

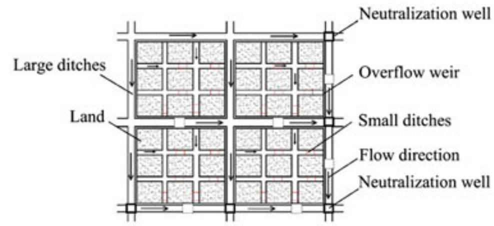

Fig. 4. Layout Ⅱ trapezoidal terrace land: Setup of neutralization well at the middle of the ditches.

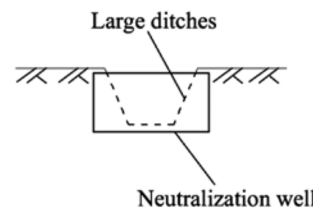

Fig. 5. Position illustration of neutralization well for large ditches.

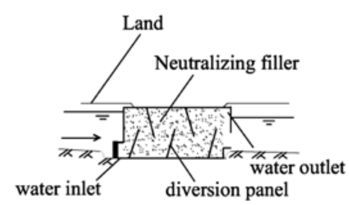

Fig. 6. Horizontal sections drawing of two-way permeable neutralization well.

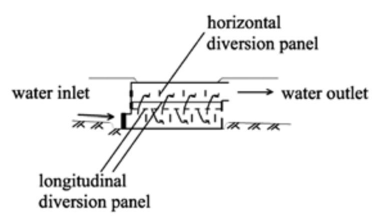

Fig. 7. Longitudinal sections drawing of two-way permeable neutralization well.

characteristics of the natural geography and the waste from industry and agriculture.

The key to the operational mode of the trapezoid escarpment system is rotation farming of grain crops. Utilizing rice planting to maximize the efficiency of the salinity removal and the transition into water-saving farming over time could both avoid soil hardening and also ensure that the crops can accommodate drought and semi-drought environments. The main measure is planting drought-tolerant vegetation with new types of irrigation, such as trickle irrigation, sprinkling irrigation and tube feeding, which would solve the problem of water resource shortages in addition to preventing soil salinization. Thus, this treatment measure would promote the growth of grain crops and improve their production and quality [19].

4.2. Indoor simulated elution experiment research based on network of the grading of trapezoidal terrace ditches

The simulation experiment was conducted indoors, followed by the monitoring of the salt content and its alkalinity and the analysis of the oil content in the soil to provide the data for realistic use. The experimental scale is a trapezoidal terrace with 0.25 square meters at the top and 1 square meter at the bottom and 0.5 m in height. The soil, which is collected from the oil-polluted saline/alkali land in Daqing oilfield, is placed in a pile and then the saline/alkali content is removed through leaching using pure water. The salt content on the surface and the slope would be examined, and the oily substances would also be monitored after elution.

Fig. 8 shows the sample analysis after 48 h of leaching. The pH of the soil was reduced significantly compared with the original value of 9.08, and the pH of the upper layer was approximately 8. Different portions of the soil were markedly reduced with respect to the alkalinity, with an average 50% reduction. Salinity and oily substance were all reduced by 50%, and the same results were found with respect to the salinity. Elution is effective in oil removal to some extent and some portions were washed away by the water. The oil content of the upper layer was increased compared to the middle and lower layers, which can be degraded quickly with the restoration of the plants and microorganisms. The indoor simulation experiment shows that it's effective to remove salinity and alkalinity using the measure of gravity sedimentation.

4.3. Auxiliary technology

The implementation of a comprehensive landscape treatment of the trapezoid terrace network would improve the soil structure effectively and fill the gaps left by adopting various physical and chemical methods and farming measures, including auxiliary technology, which would help to prevent soil hardening, to maintain the ground water level, and to mitigate the salinity

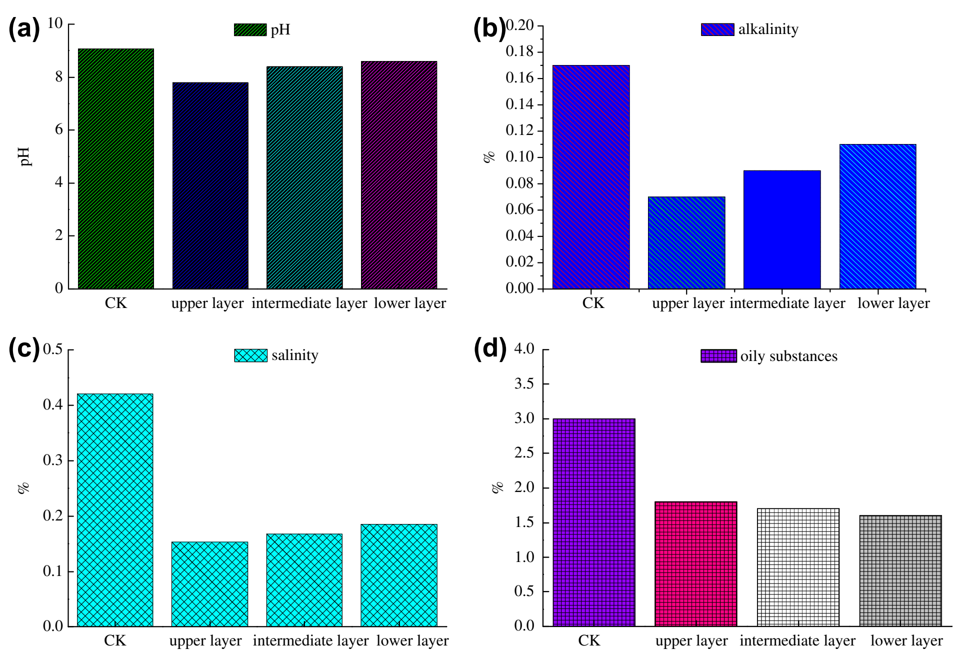

Fig. 8. The content change in the soil after elution: (a) pH, (b) alkalinity, (c) salinity, (d) oily substances.

and alkalinity [19]. The common physical improvement measures include soil mixing, land formation, sand and pressing salinity, blended sand improvement, irrigation with drainage and leaching, sediment, deep plowing, and isolation (such as coarse sand, chad, and stove ashes) [17]. Planting with plastic film mulching can help reduce evaporation and control the upward migration of the soil salts. Adding organic fertilizer would increase the concentration of the soil organic matter and humus acidity, buffering the soil reactions and controlling the toxic effects on the grain crops caused by the accumulation of harmful salts [17,19]. At some sites, according to the characteristics of the salinity, adding certain chemicals, such as desulfurization gypsum, ardealite, and industrial waste acid, could counteract the salinity. Such chemical improvement occurs via the interaction among the ions; for example, the increase in Ca^{2+} would decrease the proportion of exchangeable Na^{+}, an action that has the advantages of easy operation, rapid effects and the cyclic utilization of industrial waste [13,20,21]. The cation-exchange capacity (CEC) is identified as an important basis influencing the soil buffering ability and evaluating the capacity of fertilizer. The chemical improvement could provide exchangeable cations, such as Ca^{2+}, Fe^{2+}, Al^{3+}, and H^{+}, to exchange with the Na^{+} on the surface of the soil colloid when neutralizing the soil alkalinity, which would decrease the concentration of Na^{+} and the pH value to improve the soil permeability and promote plant growth [22]. It is worthy to optimize the coordination of the ion when the chemical methods are applied in saline/alkali land with the maximum performance. Research shows that when N, P, Mg, and water were supplied in combination, plant growth increased more than 16-fold [23]. Supply of these resources interacted to influence both plant growth and function.

4.4. Solid technology in the later stage

Improving saline/alkali soil by using vegetation, grain crop, and microorganism techniques is enduring and steady, which could be identified as a follow-up safeguard of the treatment effects of the escarpment technology [24–25]. Moreover, the biological techniques have the advantages of low investments and good effects that could slowly change the microclimate, with permanent characteristics and persistence. It has been found to be the most economic and efficient way to recover the vegetation of saline/alkali soil via an artificial seal around pasture and planting areas using the growth of local grasses and shrubs. Some salt-tolerant corps (wheat and rice) and trees through different biotic improving means, such as conventional breeding, marker-assisted selection and genetic engineering [25]. Thus, the rate of vegetation evolution from damaged vegetation to high-economic-value vegetation would be increased, and the area of the plant community would also be increased.

A large quantity of tests from other researches indicate that halophytes have the ability to control the accumulation of salt at the surface of the soil, fertilize the soil and increase the soil capacity to improve the permeability, which are beneficial to the activity of soil microorganisms and the accumulation and activation of nutrients. The halophytes include *Suaeda glauca, Tamarix chinensis, Nitraria, Apocynum venetum, Medicago sativa, Puccinellia tenuiflora, Melilotus albus, Flaveria Bidentis* (L.), *and Vitex trifolia var.simplicifolia Cham* [17,26–27]. Because the vegetation form of the Daqing area is temperate grassland and the natural vegetation is Mongolian flora, herbaceous plants dominate this area, including *Puccinellia tenuiflora, Leymuschinensis, Suaeda glauca, Phragmites australis, Calamagrostis epigejos, Axyris amaranthoides Linn*, and *Equisetum arvense Linn* [8]. Accordingly, it is obvious that the resource of indigenous plants is quite rich. In addition, planting certain grain crops with a better adaptability, such as *Hordeum vulgare, Vicia fa*ba, Beta vulgaris and *Helianthus SP*, is also good for improving a saline/alkali soil [17].

The fundamental biological treatment method uses organic matter to improve the soil properties. Saline/alkali-tolerant plants are then planted to loosen the soil structure, enhance the permeability and storage capacity of the soil and reduce the pH and salt in the ground surface, thereby inhibiting any increase in salt [28]; the salt is simultaneously moved downward by leaching and permeation. The organic acids formed by the hay and plant debris during the decomposition process, similar to green manure, will neutralize the alkali salt to increase the content of organic matter in the soil and improve the microenvironment of the rhizosphere, which is conducive to microbial activity and, thus, improves the soil fertility and inhibits salt accumulation [19]. Although its effectiveness is slow, the biological method overcomes handling large amounts of fertile soil in the soil dressing method and the water waste involved in the drainage method. In addition, the application of the biological method is acceptable for a long time. Following the gradual principle, the order is arranged rationally during the process of vegetation recovery. The order for planting vegetation, crops, shrubs, and trees should be determined rationally in combination with the establishment of grassland enclosures and the construction of farmland shelter forests to consolidate the efforts of the comprehensive treatment, soil conservation and water conservation, increasing the land covering rate and reducing the salt accumulation [25].

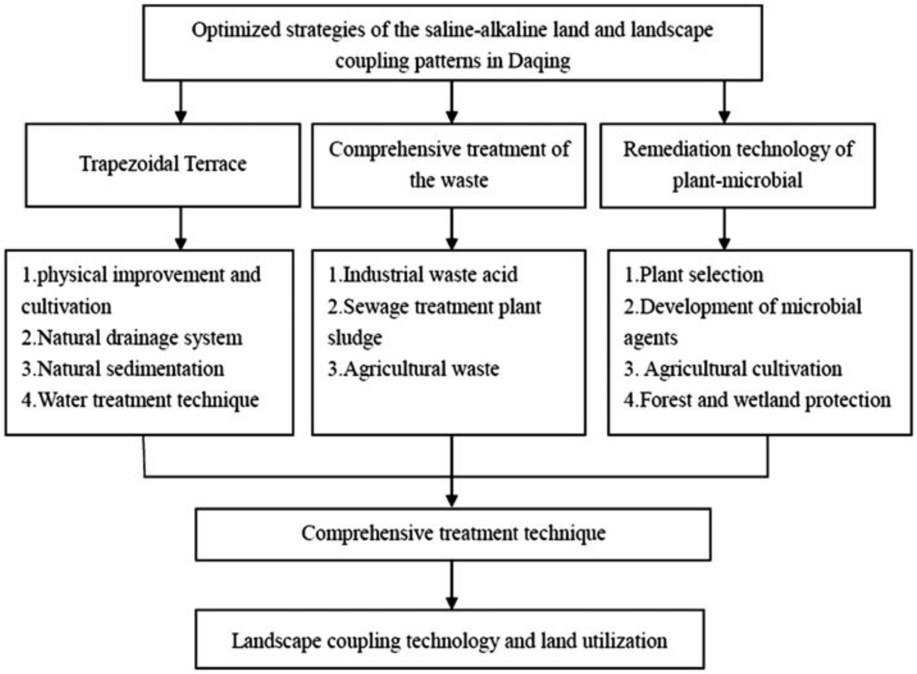

Fig. 9. Flow chart of the comprehensive landscaping treatment of the saline/alkaline land based on the trapezoidal terrace.

4.5. Strategies and procedure for comprehensive landscaping treatment of trapezoidal terrace saline/alkali land

Saline/alkali land treatment, which covers a large area with great influence to other levels, should be upgraded as a planned development strategy from one pure technological operation within the city and even regional scale. The comprehensive landscaping treatment technology considers the transformation and eco-recovery of the saline-alkali land in Daqing and the urban regeneration, landscape planning and industrial economy uniformly from a new perspective. Creativeness is utilized during the land-use process to incorporate pastures, woodlands, vegetation, fish ponds and wetlands, which are derived from the treatment process, into a system of urban eco-parks, eco-agricultural tourism and leisure tourism to form a sustainable development force. New ways and methods to deal with saline/alkali land are therefore developed with the strong economic support and sustainable development impetus for itself (see Fig. 9).

5. Conclusions

Saline/alkali land involves in complicated geographical factors and human activities in its treatment and improvement, which rarely leads to long and stable result only with single or two ways. Treatment of saline/alkali land for the oilfield in Daqing is incorporated into the view of city renewal and land use to fully exert the mutual advantages among physical, chemical and biological methods, attempting to establish the comprehensive treatment technique. The landscaped network of the grading of trapezoidal terrace ditches with natural dialysis serves as a platform, supplemented by the appropriate cultivating measure. The supporting technologies include integrated utilization of waste, integrated rehabilitation of microorganism and plants, which offer new angles and optimized treatment patterns for protection and development of saline-alkali land in Songnen Plain. And what's more important is that this new angle incorporates the procedure of saline/alkali land treatment into landscape planning , realizing the interaction and multi-objectives among ecological restoration, agricultural production and city industrial development. The technology of network of the grading of trapezoidal terrace ditches demonstrates the rapid effect in treatment comparing with the steady and stable function for the technology of plants, crops, and microorganism. The organic combination of these two technique could provide the subsequent support for the treatment of saline/alkali land with larger economic benefit and effective sustainability.

References

[1] Z. Wang, S. Zhu, R. Yu, Chinese Saline-Alkali Land, Science Publisher, Beijing (in Chinese) 1993.

[2] P. Rengasamy, Soil processes affecting crop production in salt-affected soils, Funct. Plant Biol. 37(7) (2010) 613–620.

[3] J. Yang, S. Zhang, Y. Li, K. Bu, Y. Zhang, L. Chang, Y. Zhang, Dynamics of saline-alkali land and its ecological regionalization in western Songnen Plain, China, Chinese Geograph. Sci. 20(2) (2010) 159–166.

[4] Heilongjiang Bureau of Land Management, Heilongjiang Soil Survey Office, Heilongjiang Soil, Beijing, Beijing Agricultural Press, 1992, pp. 277–278 (in Chinese).

[5] L. Zhao, Q. Shang, C. Li, Research and problems of the improvement and utilization of sodic soil status in Songliao Plain, J. Jilin Agric. Univ. 22 (Album) (2000) 79–83, 85 (in Chinese).

[6] P.D. Khasa, B. Hambling, G. Kernaghan, M. Fung, E. Ngimbi, Genetic variability in salt tolerance of selected boreal woody seedlings, Forest Ecol. Manage. 165 (2002) 257–269.

[7] Z. Plaut, M. Edelstein, M. Ben-Hur, Overcoming salinity barriers to crop production using traditional methods, Crit. Rev. Plant Sci. 32(4) (2013) 250–291.

[8] D. Liu, W. Gong, Evaluation of site quality for saline-alkali soil in Daqing, Sci. Soil Water Conserv. 7(3) (2009) 98–103 (in Chinese).

[9] Y.R. Wang, S.Z. Kang, F.S. Li, Saline water irrigation scheduling through a crop water-salinity production function and a soil-water salinity dynamic model, Pedosphere 17(3) (2007) 303–317.

[10] B. Pan, W. Gong, Z.g. Zhang, C. Liu, Classification and evaluation of the soda-saline soil in Daqing, J. Northeast Forestry Univ. 34(2) (2006) 57–59 (in Chinese).

[11] J.D. Rhoades, J. Loveday, Salinity in irrigated agriculture, Irrigation Agric. Crops Agron. Monograph 30 (1990) 76–81.

[12] W. Wang, J.-c. Xie, J.-m. Huang , X.-w. Si, Study on the new improvement mode for the saline land, J. Water Resour. Water Eng. 209 (5) (2009) 117–122 (in Chinese).

[13] H. Zhou, L. Zhang, F. Yu, P. Li, Review and prospect of China's saline-alkali soil improvement, Modern Agricultural Science and Technology, (11) (2007) 159–164 (in Chinese).

[14] J. Zhang, S. Qiu, Preliminary study on drainage standard for saline-sodic lands in arid zones, J. China Agric. Univ. (2, supplement) (1997) 141–146 (in Chinese).

[15] K. Zhao, W. Zhang, H. Fan, Biological measures for utilization and development of salinized soil, Chinese, J. Soil Sci. 32 (S0) (2001) 115–119 (in Chinese).

[16] X. Shi, Y. Fang, H. Zhao, X. Zhang, Saline-alkali soil and the selection and breeding of salinity species, Quart. Forest By-product Speciality China 4(2) (2005) 60–62 (in Chinese).

[17] Z. Yang, J. Wang, Y. Ji, M. Hu, H. Liu, Research on ecology of three systems for transforming saline land, Agric. Res. Arid Areas 19(4) (2001) 92–96, (in Chinese).

[18] Q. Wu, Irrigation and drainage technology of rice on the saline-alkali land, Liaoning Agric. Sci. 4 (1999) 45–47 (in Chinese).

[19] E. Chen, R. Wang, C. Wang, The role of organic improvement saline-alkali land, Chinese J. Soil Sci. 18(5) (1984) 193–196 (in Chinese).

[20] Y.-c. Shao, S.-r. Ren, X.-j. Lian, X.-w. Zeng, Effects of combined applications of organic matter and gypsum soil amendments on salinized soils, J. Soil Water Conserv. 23 (5) (2009) 175–178, 183 (in Chinese).

[21] C.G. Suhayda, L. Yin, R.E. Redmann, J. Liz, Gypsum amendment improves native grass establishment on saline-alkali soils in northeast China, Soil and Manage. 13 (1) (1997) 43–47.

[22] G. Xiao, C. Luo, H. Bai, F. Zhang, Research on the amount of desulfurized gypsum from the coal-burning power plant applied to improve the alkalized soil for paddy rice, Ecol. Environ. Sci. 18(6) (2009) 2376–2380, (in Chinese).

[23] J.J. James, R.L. Tiller, J.H. Richards, Multiple resources limit plant growth and function in a saline-alkaline desert community, J. Ecology 93 (2005) 113–126.

[24] M. Shahbaz, M. Ashraf, Improving salinity tolerance in cereals, Crit. Rev. Plant Sci. 32(4) (2013) 237–249.

[25] S.-C. Jiang, N.-P. He, L. Wu, D.-W. Zhou, Vegetation restoration of secondary bare saline-alkali patches in the Songnen plain, China, Appl. Veget. Sci. 13 (2010) 47–55.

[26] M. Chai, F. Shi, K.S. He, R. Li, D. Cao, Z. He, Effects of Saline-alkaline stress on early growth strategy and colonization success of *Flaveria bidentis* (L.) Kuntze Asteraceal—A New exotic plant in Northern China, Polish J, Ecology 60(3) (2012) 559–565.

[27] J. Xi, S. Xing, J. Zhang, Y. Song, Comparison of several amelioration models for high saline-alkali soil, J. Northeast Forestry Univ. 31(6) (2003) 99–101 (in Chinese).

[28] J. Guo, S. Jiang, G. Sun, Comparative study on remedy ways of saline alkali grassland in Songnen Plain, Chinese J. Appl. Ecology 9(4) (1998) 90–93 (in Chinese).