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Original Article

Sustainable Ground Water Treatment Plants Sludge Recycling System Development via SWOT

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Abstract *- The results of studies of iron-containing sludge (hereinafter referred to as ICS) from wash waters of groundwater iron removal stations prove the perspectives of its application in a wide range of industries. The shortcomings of existing systems for recycling ICS and prospects for their modernization considering current global trends and the regulatory framework of the Russian Federation have been identified. The system for recycling ICS into final marketable products is proposed using the example of consumables for nondestructive testing. In the proposed system of recycling ICS, functional subjects are identified as responsible for various stages of the transformation of secondary resources into secondary raw materials and/or final products. The section of the system that has the least level of theoretical and practical elaboration was identified and accepted as an object for SWOT analysis. At least 5 key factors were identified for each element of the SWOT analysis, and a SWOT analysis matrix was created containing 15 proposed implementation measures to intensify ICS's introduction into economic circulation. Gaps in knowledge and regulatory framework in the field of application of "secondary resources" were identified. Research priorities and future challenges are discussed to support developing and applying effective management methods for iron-containing sludge from iron removal stations using multi-pronged strategies. The prospects of the influence of weaknesses and threats leveling have been predicted, as well as the influence of strengths and opportunities increasing for widespread implementation of recycling practices in water utility acceleration.*

Keywords *- Alternative raw materials, Circular economy, Iron-Containing Sludge, Sustainable Development, SWOT analysis.*

1. Introduction

Despite the differences in technological patterns and regulatory documents, engineering solutions in the field of groundwater treatment have significant unification throughout the world and in the BRICS+ members in particular. This assessment is evenly true to the core technologies of the groundwater treatment process in terms of iron removal and reduction of excess mineralization, including the aeration process.

The methods and tools described in the study were selected considering the possibility of their further replication in any region where centralized use of groundwater is carried out. Technological schemes of iron removal stations at the final stage include rapid filters, which retain the oxidation products of iron compounds present in groundwater.

After filter washing, iron compounds pass into the wash water, which, in accordance with the principles of Sustainable Development, should be returned to the water treatment cycle after removing iron-containing sludge (hereinafter referred to as ICS) from it [22]. According to the Russian federal classification catalog of waste, ICS and their derivatives belong to hazard class V or IV [4].

Iron-containing sludge can be involved in production in accordance with the principles of the circular economy as a secondary resource and/or raw material from waste [6]. This becomes possible due to changes in Russian legislation, especially Federal Law No. 268-FZ "On Amendments to the Federal Law "On Production and Consumption Waste" and Certain Legislative Acts of the Russian Federation", 2022 [5]. This law introduced concepts and regulatory terms such as "waste collection", "secondary resources", and "recycled raw materials". Applying this regulatory frame is systemizing and legal already existing practices of the local circular economy. Despite that the massive use of such technogenic waste and secondary raw materials based on them has not yet found widespread industrial application.

In 2024, successful cases of sustainable technological and economic system creation are still not widely known. This research was set up to highlight the barriers that decrease the speed of such systems creation and propose an evaluation system for further implementation risk management.

One of the reasons for this is the concentration on local areas of their possible implementation. At the same time, aspects of global, systemic advantages and risks of their widespread involvement in economic turnover are not sufficiently considered.

The finely dispersed structure, intense color, and the ability to change color depending on the processing temperature make it possible to use ICS as a raw material for the production of pigments [9]. The required color of building products, while improving the strength characteristics, can be obtained by directly adding ICS to the composition of raw materials to produce building materials [7].

The use of ICS in natural and wastewater treatment technologies is promising. ICS particles have a large specific surface area and well-developed mesoporosity, which allows them to be used as a sorption material [11]. The use of ICS in its native state causes difficulties in separating such a sorbent from water. The problem is solved by modifying raw materials to produce magnetic and granular adsorbents [23]. The production of sorption materials from ICS made achieving a high degree of extraction of arsenic compounds from water possible [13, 24].

The production of nanosized magnetic sorbents based on ICS, effective for treating wastewater containing petroleum products, dyes and pharmaceuticals, is promising [9, 17]. Ferromagnetic nanoparticles produced from ICS can potentially remove a large amount of low molecular weight organics during coagulation of surface source waterpipe [1, 23].

Modifying fireclay granules used as loading for deferrization filters with synthetic iron nitrate obtained from ICS increases the efficiency of water deferrization [18]. Another option for effectively loading filters for iron removal of groundwater based on ICS was obtained as a result of the synthesis by burning anthracite granules pre-coated with iron oxide [19]. All listed examples of ICS involvement in product manufacturing relate to the laboratory research stage.

ICS is a key component of groundwater iron removal stations' technogenic raw material base. However, the lack of information about benefits and risks reduced to a unified model is a significant limiting factor when making management decisions on the modernization of technical and economic systems that allow the effective use of ICS.

This study aims to form a SWOT analysis matrix, including information on the technical, economic and environmental aspects of sludge from iron removal stations, which can be a tool for decision-making by specialists responsible for involving waste in economic circulation.

2. Materials and Methods

2.1. Research Area and Data (Materials)

Sludge from rinsing waters from groundwater iron removal stations, which is a technogenic waste and requires a search for disposal areas in accordance with the Sustainable Development Goals (SDGs), is a research material. The study results of ICS's resource properties were systematized and published earlier.

2.2. SWOT Analysis Method

The SWOT analysis method developed in the 1960s at Harvard Business School was used to assess the potential and risks of using groundwater treatment sludge to produce ultrafine powders [8].

The abbreviation has the following interpretation: S (Strengths) – object's strengths, W (Weakness) – its weak points, O (Opportunities) – opportunities coming from the external environment, T (Threats) – threats lurking in the external environment. Initially, SWOT analysis was carried out in the context of a business environment for the purpose of developing business strategies. Currently, SWOT as an analysis method is used in various fields [21].

SWOT analysis can be done using a matrix. The methodology for conducting a SWOT analysis involves several stages. In the first stage, questions for developing the matrix are identified. In the second stage, the strengths and weaknesses of using the technology for the production of ultrafine powders from the sludge from iron removal stations are determined.

In the third stage, opportunities and threats are identified. The arguments are summarized and ranked in order of priority, starting with the most important. In the fourth stage, a cross-comparison of strengths and weaknesses with opportunities and threats is carried out. Data were collected and analyzed based on publications and the authors' previous research results.

The study used a classic scheme: in the field of strengths and opportunities, a maximization strategy is proposed; on the field of strengths and threats - a strategy of maximizing strengths and compensating for threats; on the field of weaknesses and opportunities - a strategy of minimizing weaknesses and strengthening opportunities, on the field of weaknesses and threats - a strategy of double minimization.

As a result of summarizing the results of the SWOT analysis, a strategy aimed at maximizing the potential of strengths and opportunities while minimizing the consequences of weaknesses and threats has been developed.

3. Results and Discussion

The following basic sludge properties, on which the higher-order elements of the SWOT analysis will be based, have been selected:

(A) – Granulometric composition [μm];
(B) – Chemical purity [wt. %];
(C) – Number of identifiable components in ICS [units].

It is important to note that when talking about property (A), it is worth considering not only the size of individual particles themselves but also the size of grains and agglomerates since the values of these parameters largely determine the conditions for the technological processes of their processing and measures taken to ensure environmental safety. The sludge is typically dumped into nearby water bodies or taken to landfills, where metal ions can be washed out by rain and contaminate soil and surface waters [14]. Research shows that landfills for finely dispersed waste disposal are sources of air pollution in nearby populated areas with PM2.5 and PM10 particles, which threaten human health [14].

The property of chemical purity (B) in this context is considered as the mass fraction of the target processing component into the final product (iron compounds, including its oxide form) compared with other components. ICS can have significant variability in properties even within the same region, which makes simplified systems for assessing benefits and risks unrepresentative and, therefore, does not allow for their widespread industrial implementation.

The variability and number of identifiable ICS components (C) is also an important factor. The less multicomponent the initial technogenic raw materials are, the lower the capital investments and operating costs are. The waste can be processed into designed products with a dominant share of positive properties. In turn, the multiplicity of chemical components increases the likelihood of obtaining non-target chemical compounds during processing, including complex chemical compounds that can make the useful disposal of ICS using existing methods and technologies irrational.

Obtaining the complete picture of the properties underlying the designed SWOT analysis model was made possible through the use of "triangulation", where each parameter under study is checked in at least 3 ways. Related barriers and methods for overcoming them are described in detail in materials published based on the results of previous stages of the study. The next stage of creating a new technical and economic system based on the principles of the Circular Economy and the UN Sustainable Development Goals was aligning separate elements into a single system. According to that purpose, data for SWOT analysis were taken from several sources such as:

- Ministry of Natural Resources and Environment of the Russian Federation;
- Russian Association of Water Supply and Sanitation;
- Government of Tyumen Region;
- Surveys on Water Supply Municipal Facilities management (8 stations);

Achieving the proposed result - creating a system for recycling ICS into final marketable products - involves the creation of new systems for organizing relationships between business entities and a division of labor system. Such systems will require significantly lengthening the chain from waste generation to its practical application in the finished product format. Visualization of the designed system and the areas of greatest attention when conducting a SWOT analysis are presented in Figure 1.

A systematic approach to the system being modernized requires visual visualization of all system elements, including those not directly involved in the processing of ICS, as well as identification of areas of positive changes resulting from implementing the proposed changes. The sustainable development goals, the achievement of which will be stimulated by the implementation of the proposed solutions, are also presented in the diagram.

The division of entities into functional groups is conditional, and the simplest types of products based on ICS (including sorbents and coagulants based on ferric chloride) can remain within the framework of a single entity – a water utility or another enterprise that carries out water treatment on an industrial scale. The scheme reflects the hypothesis about the optimal balance of the functionality of business entities, developed, among other things, based on negotiations with industry experts and managers of enterprises that use products, as well as objects of the water management complex.

The following group of sequential processes was selected as the object of the SWOT analysis:

- Collection and accumulation of ICS, as well as wash waters containing them from iron removal stations;
- Pre-treatment of wash waters and ICS, including separation into dewatered sludge and water of sufficient quality for circulation and re-purification. This approach further reduces the costs of transporting ICS to the processing facility;
- Processing of ICS into an intermediate product – ferromagnetic iron-containing particles. In this form, the particles can be used as a raw material component of a high degree of readiness for the production of high-tech final products (including catalysts for the production of high-viscosity oil, materials for LFP batteries) or the creation of finished products (including magnetically sensitive pigments and consumables for magnetic particle inspection using the dry method).

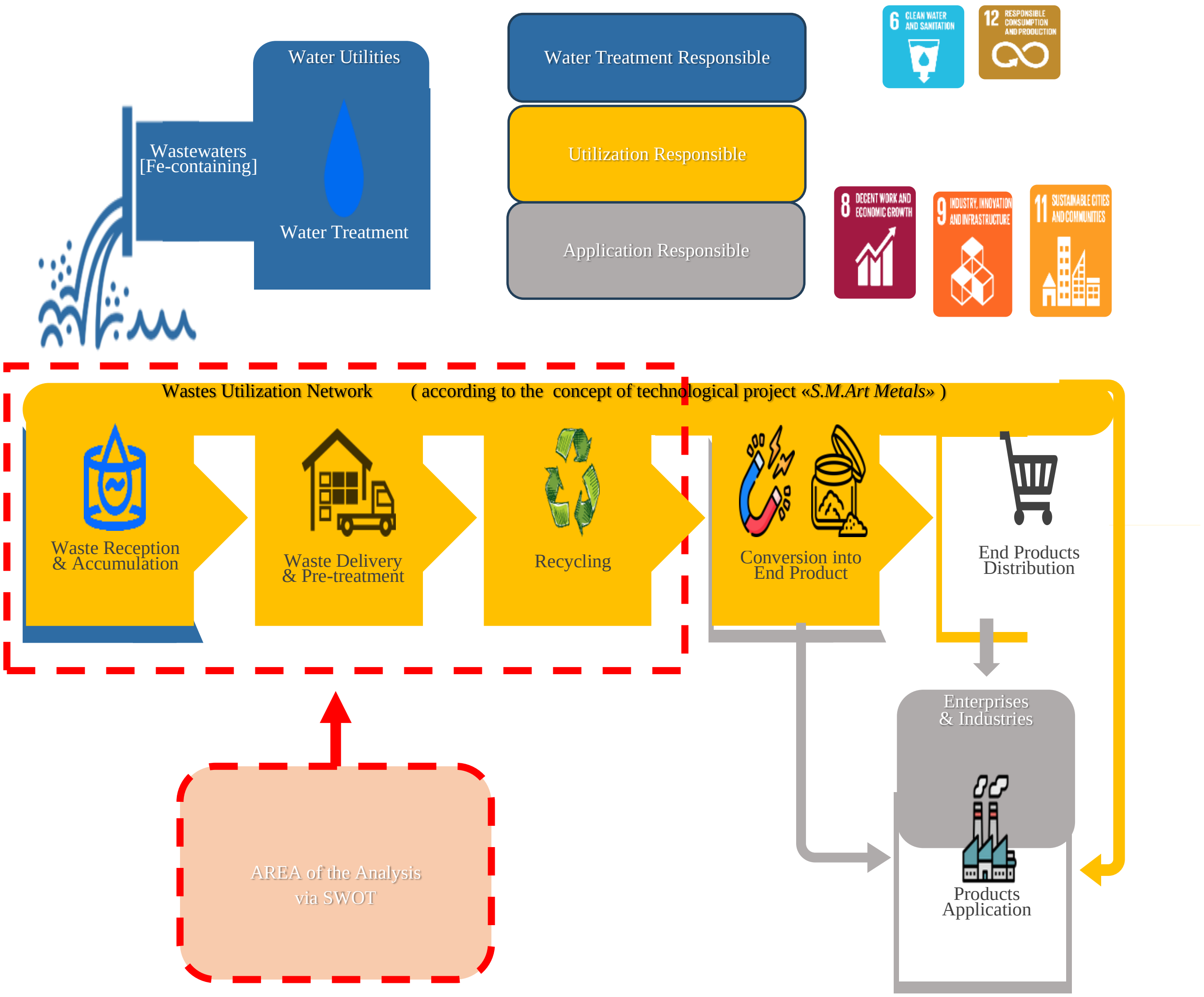


Fig. 1 Scheme for organizing ICS processing "Waste – Products"

As the most illustrative example of the applicability and prospects of ICS in the creation of the circular economy subsystems, consumables for Magnetic Particle Inspection (MPI) were considered. ICS-based MPI consumables were developed and successfully passed pilot tests during research in 2021-2024. MPI is widely used for magnetic-powder nondestructive testing. MPI is actively used to check the quality of welds and identify other defects on magnetically sensitive steels, products and structures, which form the basis of the municipal infrastructure of most cities and industrial enterprises.

Due to the high level of metal consumption of utility networks and structures of the water management complex, the creation and use of MPI within the circuit of water utilities will be a clear example of implementing the principle of a circular economy. They, therefore, will aim to achieve SDG 12 and SDG 11.

In 2023-2024, a significant contribution to the verification of this hypothesis was made with the participation of FERRME GROUP LLC, which developed, tested and patented consumables for MPI based on ferromagnetic particles obtained from ICS and having a dispersion of 2.0 μm (d90). Tests were supported by the Industrial University of Tyumen and NDT Rus LLC – regionally known centers of expertise in nondestructive testing. Testing was carried out using a control sample MO-3. This control sample has five preset defects with different depths. Control sample MO-3 is equivalent in its properties and method of checking the quality of finished consumables for MPI to the sample indicated in Figure X1.2 in Appendix X1 [3]. Equivalent testing can be held using a control sample of a similar type – KETOS Tool Steel Ring, described in Figure X7.1 in Appendix X7 (AISI KETOS Tool Steel Ring) [3]. Magnetization was carried out using a portable universal magnet, RM-5.

Figure 2 contains a microphotograph of processed ICS made by electron microscope TESCAN MIRA3 LMU. Submicron and nanoscale of particles can be seen.

Figure 3 contains a photograph of the control sample MO-3 with a flaw detection pattern. The initial dispersion of the sediment is 2.0 μm (d90), as well as the high degree of roundness and sphericity of the particles (according to the Krumbien-Schloss diagram – at least 0.4 for each parameter) provide a result sufficient for implementation at urban infrastructure facilities as defect control tools.

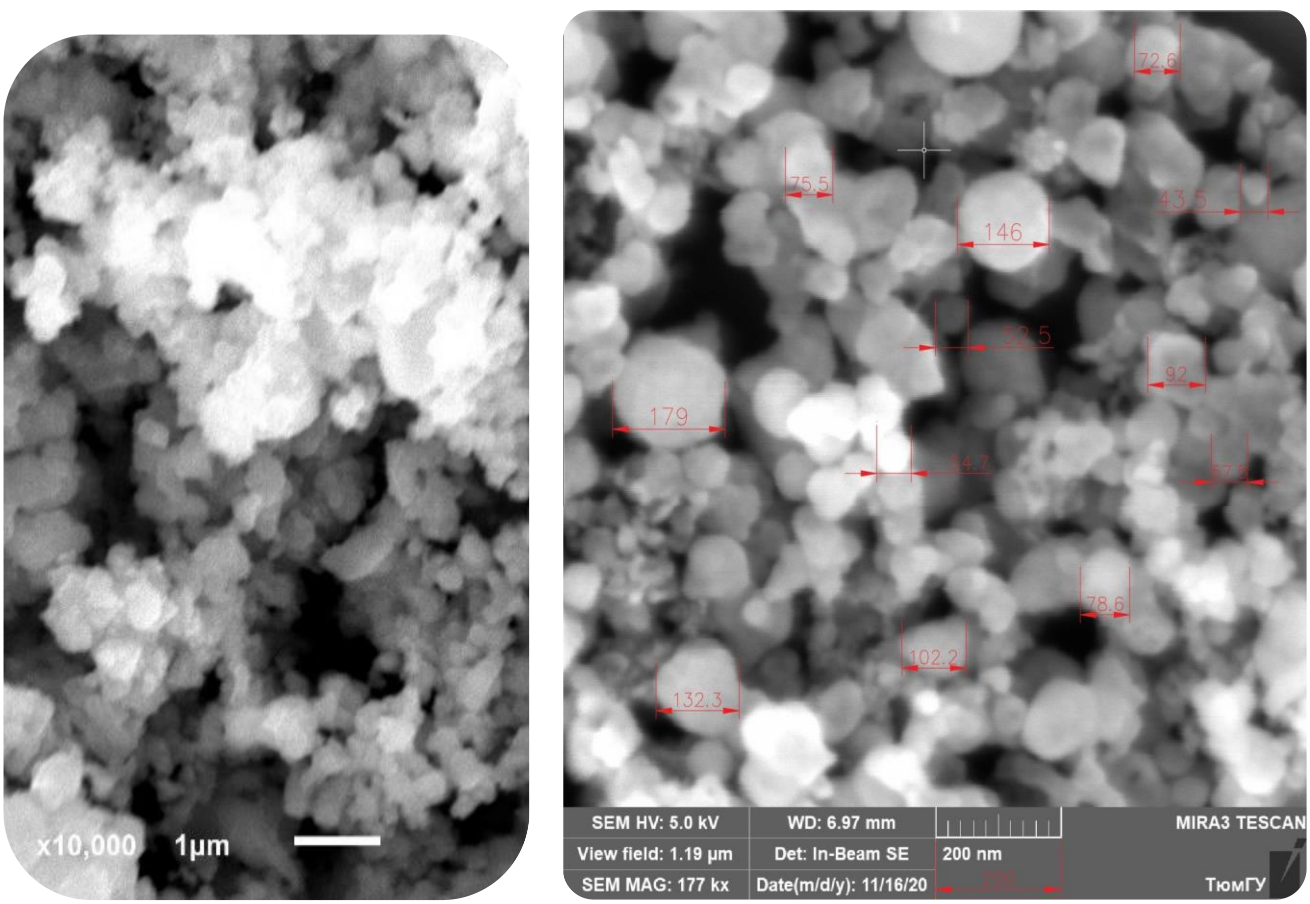
This solution is one of the elements to reduce accident rates in water and heat supply networks through accurate and timely diagnosis of hidden damage.

Returning to the group of sequential processes selected for SWOT analysis as a unified subsystem, it is worth noting that all of the listed stages have common properties, namely:

1. Lack of ready-made engineering solutions for implementing the process;
2. A high degree of uncertainty when making decisions about choosing a specific engineering solution and/or technological processing mode.

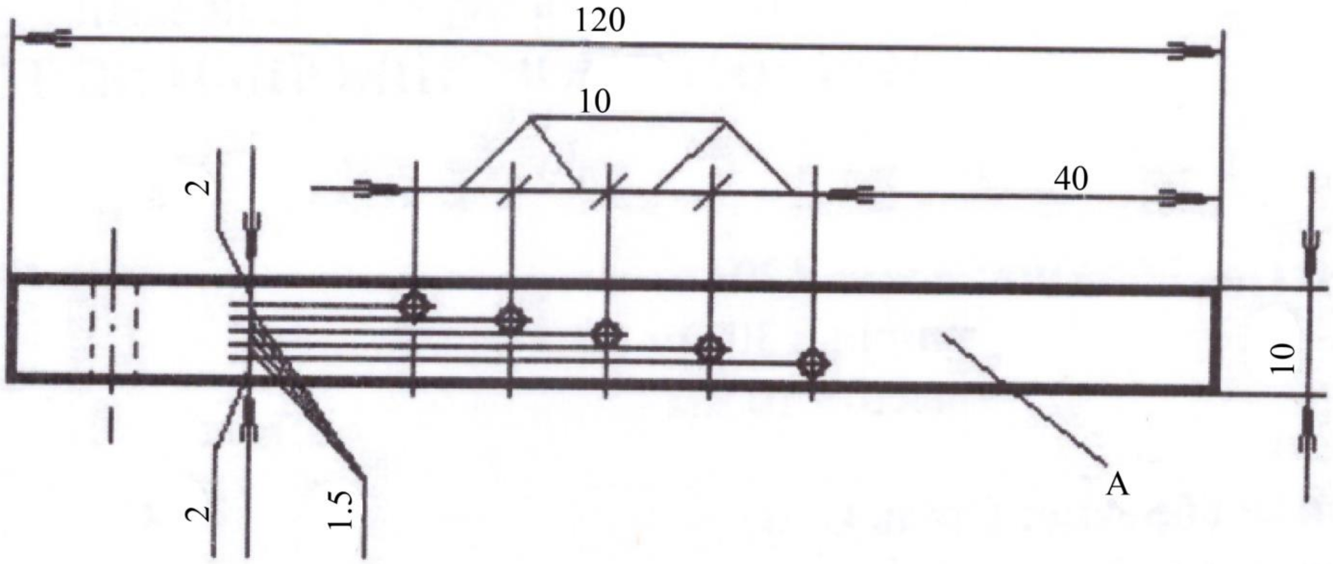
This situation is directly related to the variability of technological schemes of the water treatment process at different stations and the different volume, composition and concentration of ICS in the wash waters. Considering the fact that the proposed changes do not affect either the water treatment process or the production process of finished products based on iron-containing ferromagnetic particles, obtained in this case as a result of processing of ICS, the stages “Water purification”, “Processing into the final product”, “Sale of finished products” and “Product Application” are not included when conducting a SWOT analysis.

The identified SWOT elements for using ICS in producing highly dispersed ferromagnetic particles were collated, integrated and analyzed to develop strategies (Table 1). Therefore, finding profitable options for reusing ICS in water treatment will be a priority as environmental and economic factors limit disposal options (e.g., landfill and sewer disposal).

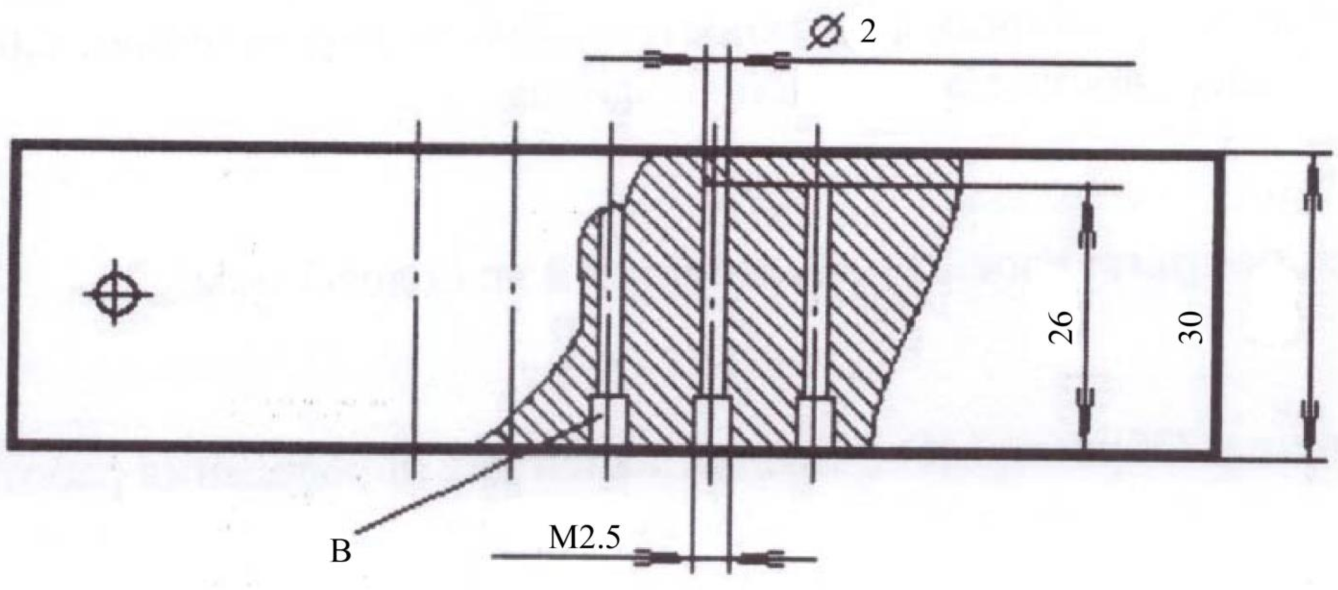


(a) (b)

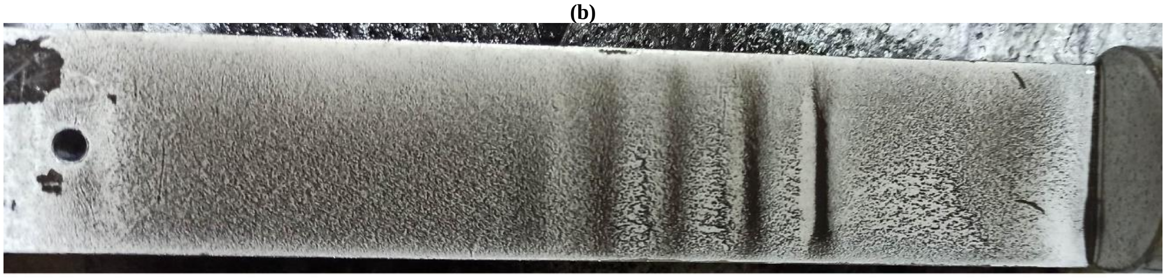
Fig. 2 Microphotographs of ferromagnetic powder particles taken using an electron microscope TESCAN MIRA3 LMU:
a – Sample #1 (3 hours of ICS processing at 600°C in the atmosphere of carbon monoxide);
b – Sample #2 (the same as Sample #1, but with the addition of 15 minutes of ultrasonic treatment in 22 kHz frequency in distilled water medium).



(a)



(b)



(c)

Fig. 3 The result of testing a sample of ferromagnetic powder obtained from the sludge from the iron removal station, as a consumable material for MPI

a – schematic representation of the control sample MO-3 with pre-installed defects (side view),

Where (A) – bar made of steel grade ST-3 (ST-3 is equal to AISI 1017 and DIN 17103);

b – control sample MO-3 (view from above), where (B) – cylindrical hole;

c – photograph of a control sample MO-3 for MPI, on which an ICS-based material is applied.

Table 1. SWOT analysis of the key cluster of the ICS process

Element-by-element SWOT analysis for ICS application in the highly dispersed ferromagnetic particles production	**S1.** Long-term predictability of the volume and quality of the raw material base; **S2.** Low cost of ICS production and processing; **S3.** Unique combination of physical and chemical properties; **S4.** Geographical prevalence of raw material generation facilities; **S5.** The technological scheme is easily scalable.	**W1.** ICS particles are classified as PM 2.5 pollutants; **W2.** Lack of experience in implementing technological complexes for treating wash water and sludge at iron removal stations; **W3.** The need for additional stages of treatment of wash water and sludge; **W4.** High variability in the composition of ICS from different sources; **W5.** Lack of experience in industrial application of ICS to create final products.
O1. Constant growth of ICS raw material base (5 – 40% over 10 years); **O2.** Development of industries requiring massive use of finely dispersed iron-containing raw materials; **O3.** The desire to increase the share of employment in highly productive sectors of the economy, including in urban agglomerations; **O4.** Reducing the proportion of PM 2.5 particles entering the atmosphere and water bodies; **O5.** The emergence of additional income opportunities for water utilities and related entities.	**S1 S5 O1** – Mapping the resource base jointly with government authorities (including the Federal Agency for Mineral Resources) to create a sustainable source of raw materials for the creation of high-tech products; **S2 S3 O2** – Development and implementation of a new product in the markets; **S4 S5 O2 O3** – Diversification of the resource base, stimulating the trend towards localization of technology production companies; **S2 O3 O5** – Creation of guidelines for water users on the implementation of new technical and economic models (including with the support of the Bureau of Best Available Techniques).	**O1 O2 W1** – Conducting additional research into the impact of ICS on the environment; **O2 W2 W5** – Informing consumers of finely divided iron-containing raw materials about the possibility of replacing traditional sources; **O3 W3** – Implementation of measures to train personnel for integration into newly created and modernized jobs; **O1 O4 W1 W3** – Creation of methods and sites for preliminary accumulation of ICS, leveling out the negative factors of the impact of PM 2.5 on the biosphere and subjects of the processing process.
T1. There are no standardized instructions for working with ICS; **T2.** There is no regulatory framework specialized for regulating the processing of ICS into commercial products [5]; **T3.** Insufficient experience in the development and operation of technological complexes (solutions) for preparing ICS for processing; **T4.** Inertia of water users to introduce new technologies; **T5.** Prejudicial attitude of consumers towards final products made from recycled materials as low quality.	**S1 S3 T1 T3** – Borrowing engineering solutions and methods in related industries (Powder metallurgy, small-tonnage chemistry and others) **S2 T3** – Creation of a patent landscape, including in foreign countries, to consolidate technological leadership in the selected sub-industry; **S3 T1 T2** – Conducting additional research into the regulatory framework, developing solutions together with the professional community (the Russian Association of Water Supply and Sanitation, the Ministry of Natural Resources and Environment of the Russian Federation …); **S2 S3 T4 T5** – Educational work regarding the predicted economic benefits from the introduction of new technological chains.	**W1 W4 T1 T3 T5** – Development of methodological materials for ICS disposal, considering the specifics of the raw material base; **W4 T2** – Creation of regulatory documents that provide a wide range of technogenic wastes and their parameters suitable for involvement in economic turnover. **W1 W3 T2 T4** – Consulting water users and related entities by industry experts, including reputable organizations (the Russian Association of Water Supply and Sanitation, the Bureau of Best Available Techniques, Competence centers created within the framework of the national project of Russia “Labor Productivity”).

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Table 2. Analysis of SWOT elements value depends on required/expending resources

Direct Value for each situation	Meaning	Resource of SWOT analysis		Background Value for Resource
0.9	Extremely important	Natural Resources (NR)		0.4
0.8	Strongly important	Financial Capital (FC)		0.8
0.7	Obviously important	Legislations & Regulations (LR)		0.6
0.6	Moderately important	Labor Resource (WQ)	Highly Qualified	0.7
			Low Qualified	0.5
0.5	Slightly important	Entrepreneurial ability (EA)		0.4
0.3-0.4	Fractionally important	Energy (E)		0.3
0.2-0.3	Insignificantly important	Time (T)		0.5
0.1-0.2	Not important	Logistics (L)		0.3

Table 3. Analysis of SWOT impact elements value depends on required/expending resources

Required / Expending Resources SWOT analysis elements for ICS application in the highly dispersed ferromagnetic particles production	Resources Impact on SWOT Analysis Elements: Natural Resources (NR)	Financial Capital (FC)	Legislations & Regulations (LR)	Labor Resource by Workers Qualification (WQ): Highly Qualified	Labor Resource by Workers Qualification (WQ): Low Qualified	Entrepreneurial ability (EA)	Energy (E)	Time (T)	Logistics (L)	Summary Impact (Sum)
S1. Long-term predictability…	0,16	0,48	0,42	0,63	0,1	0,36	0,09	0,45	0,18	**2,87**
S2. Low cost of ICS…	0,32	0,24	0,12	0,56	0,3	0,36	0,21	0,25	0,27	**2,63**
S3. Unique combination…	0,36	0,64	0,3	0,49	0,15	0,32	0,06	0,25	0,15	**2,72**
S4. Geographical prevalence…	0,36	0,4	0,18	0,49	0,3	0,2	0,21	0,35	0,27	**2,76**
S5. The technological scheme…	0,28	0,64	0,3	0,56	0,35	0,32	0,15	0,25	0,09	**2,94**
W1. ICS particles are classified as PM 2.5…	0,2	0,4	0,54	0,21	0,05	0,16	0,12	0,1	0,24	**2,02**
W2. Lack of experience in implementing…	0,12	0,4	0,48	0,63	0,3	0,32	0,12	0,45	0,21	**3,03**
W3. The need for additional stages…	0,24	0,72	0,48	0,49	0,3	0,28	0,27	0,35	0,15	**3,28**
W4. High variability in the composition…	0,36	0,4	0,48	0,63	0,2	0,36	0,15	0,25	0,09	**2,92**
W5. Lack of experience in industrial…	0,24	0,64	0,54	0,63	0,15	0,36	0,15	0,45	0,12	**3,28**
O1. Constant growth of ICS…	0,36	0,72	0,54	0,35	0,15	0,28	0,21	0,3	0,27	**3,18**
O2. Development of industries…	0,24	0,72	0,48	0,63	0,4	0,36	0,27	0,35	0,27	**3,72**
O3. The desire to increase the share…	0,32	0,56	0,18	0,42	0,05	0,28	0,06	0,15	0,24	**2,26**
O4. Reducing the proportion of PM 2.5…	0,28	0,24	0,54	0,56	0,15	0,16	0,18	0,4	0,24	**2,75**
O5. The emergence of additional income…	0,24	0,72	0,18	0,49	0,45	0,36	0,18	0,2	0,21	**3,03**
T1. There are no standardized instructions…	0,24	0,24	0,54	0,63	0,4	0,36	0,06	0,4	0,09	**2,96**
T2. There is no regulatory framework…	0,12	0,32	0,54	0,63	0,35	0,36	0,06	0,25	0,15	**2,78**
T3. Insufficient experience…	0,08	0,4	0,48	0,63	0,4	0,32	0,06	0,4	0,09	**2,86**
T4. Inertia of water users to introduce…	0,08	0,64	0,54	0,63	0,45	0,36	0,06	0,4	0,06	**3,22**
T5. Prejudicial attitude of consumers…	0,16	0,24	0,48	0,49	0,2	0,36	0,06	0,35	0,06	**2,4**

Developing a strategy for finding opportunities for producing magnetic powders and solving environmental and legal issues will be in demand. The capabilities of the new raw material base of fine iron-containing raw materials must be supported by the development of information resources for industries potentially interested in such raw materials.

Water utilities are looking for sources of additional income. The development of guidelines for implementing new technical and economic models will lead to the interest of such organizations in implementing complexes for the treatment of wash water and sludge at iron removal stations and their search for a market for the product. When analyzing threats and strengths, it is proposed that a strategy for borrowing engineering solutions and methods in related industries be developed.

Considering the dynamic change in legal regulation in 2024-2025, additional research into the regulatory framework regarding the involvement of ICS in the economic activities of cities and large industrial enterprises will be relevant. The professional community, for example, the Russian Association of Water Supply and Sanitation, can become the initiator of such work. To overcome the inertia of water supply and sewerage organizations, it is necessary to conduct educational work, for example, through participation in corporate conferences.

If weaknesses prevail, then external opportunities need to be considered. Worldwide growth in the use of additives for oil production and refining and the production of lithium-ion batteries, including LFP and NFPP batteries, is observed [2, 16, 20]. Fine additives based on iron compounds, used in these industries, are still produced on other raw material bases, as a rule, using iron salts, alkalis, acids and other reagents, which are, in most cases, non-renewable resources. The use of some of these reagents may be hazardous to the environment and human health.

Therefore, it is important to show the advantages of raw materials from sludge from iron removal stations, which have unique properties, low cost, simplicity and safety of the technological process for obtaining the final product [12]. Measures to train personnel for integration into newly created and modernized jobs are necessary.

An additional assessment of the threat of ICS to the environment and the development of methods and structures for the preliminary accumulation of sludge that neutralizes its negative impact on the biosphere and subjects of the processing process are required. To overcome weaknesses and threats, the development of regulatory documentation regarding the involvement of ICS in production and methodological materials for the disposal of ICS in accordance with the principles of the circular economy is required.

Consultation with water users and related entities can be carried out by such organizations as the Russian Association of Water Supply and Sanitation, the Bureau of Best Available Techniques, and Competence centers created within the framework of the national project of the Russian Federation “Labor Productivity”. Further stages of research will be developing and unifying this methodology, considering specific goals, tasks and metrics of international and state-owned programs in labor productivity improvement, environmental and waste management, the efficiency of water resources, etc.

4. Conclusion

The gradually increasing amount and unique properties of sludge from wash water from iron removal stations necessitate the search for disposal areas as raw materials for high-tech industries, as well as their evaluation. An analysis of the main areas of application of iron-containing sludge showed that ICS processing technologies are still in the experimental stage. SWOT analysis was used to evaluate the use of ICS in producing highly dispersed ferromagnetic particles from the following four perspectives: problem-solving, environment, laws and regulations and technology development. It has been found that the production of fine magnetic iron powder is a promising technology since products based on it are of high value.

However, the need to introduce additional stages of sludge treatment at stations, the lack of experience in such processing and experience in the use of technogenic raw materials, the lack of a regulatory framework regulating the processing of ICS into marketable products, and the inertia of water users so far hinder the practical use of technogenic raw materials generated by groundwater iron removal stations. The proposed strategies will maximize the potential of strengths and opportunities while minimizing the consequences of weaknesses and threats.

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