Solving Environmental Problems in Leather Production by Implementing an Original Process Flow and Using New Materials

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Abstract

The Federal Law “On the Protection of Lake Baikal” aims to comprehensively protect its ecosystem and promote the sustainable development of adjacent territories. Strict requirements for the quality of discharged wastewater prevent the processing of leather and fur raw materials in the central, buffer, and atmospheric zones of the specially protected area of Lake Baikal. It is known that industrial processing of raw hides and skins requires large volumes of water, which creates challenges associated with treating significant quantities of toxic wastewater.

This prompted us to develop new raw hide processing methods that virtually eliminate dyes, organic tanning agents, and fatliquoring agents from wastewater, significantly reduce chrome tanning agent consumption (by 32%), and shorten the production cycle by 4-5 times. This was made possible by new methods of introducing chemicals into the dermis, ensuring that the chemicals are completely absorbed into the semi-finished product, eliminating wastewater.

The aim of this work is to find solutions to environmental problems in leather production by implement- ing an original process flow diagram and using new materials.

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This work proposes a new, original raw hide processing flow diagram in which dyeing, retanning, and filling are performed before the main tanning and fatliquoring with chromium compounds. A mechanism for intensive mass transfer of the materials used into the dermis has been developed. At the same time, the number of technological processes is reduced from 10 to 6, and their duration, including pickling, tanning, dyeing, retanning, filling, and fatliquoring, is reduced from 20-27 to 4-5 hours. The quality of the finished leather complies with the standards of Russian Federation Standard 939-2021 “Leather for Shoe Uppers. Technical Conditions.” The proposed approach is also applicable to the tanning of other types of leather, such as clothing leather.

Keywords: leather technology, ecology, technological processes, flow chart.

1. Introduction

Wastewater from tanneries contains a large number of various chemical compounds. The main parameters monitored are: pH, solids, Chemical Oxygen Demand (COD), Biological Oxygen Demand (BOD), Ntrogen (Kjeldahl nitrogen), ammonium nitrogen, sulfides, neutral salts (sulfates, chlorides), fats, chromium III and chromium VI compounds, other metals (aluminum, zirconium), solvents. The legislation of countries involved in leather

processing sets standards for wastewater pollution control and has strict regulations. These standards vary from country to country. EU countries lead in the strictness of regulatory indicators. India, China, and Brazil have relatively, soft standards. Maximum permissible concentration (MPC) for wastewater from industrial enterprises in Russia vary depending on the region.

The Lake Baikal, containing 20% of the world's fresh water, is protected by the Federal Law "On the Protection of Lake Baikal" [1]. The territory around the lake belongs to the specially protected Baikal natural area and contains three ecological zones - the central (the lake itself and the coast), the buffer (catchment area) and the zone of atmospheric influence (up to 200 km to the west/northwest).

The Ministry of Natural Resources of the Russian Federation has adopted the following maximum permissible concentrations of harmful substances in wastewater discharged into water bodies within the Baikal Natural Territory: BOD, MgO2/dm3 – 2.1; COD, mgO2/ dm3 – 34; chromium (total Cr3+ and Cr6+) – 0.008 mg/ dm3. Wastewater discharged directly into Lake Baikal should be virtually free of chromium – 0.000077 mg/dm3

[2]. Given the strict requirements for discharged

Time,

min. Digital image processing Histogram, of colored pixels

8

Fig 1 – Leather sample processing at 8 minute of tanning process

wastewater, the operation of enterprises, especially leather and fur industries, in this area is impossible without deep wastewater treatment.

A natural way out of this situation is to search for new approaches and adopt innovative solutions, which is the goal of this study.

2. Research Materials and Methods

The primary object of the study was pelt after the pickling process, prepared using the same method as shoe upper leather. The pickling degree was 100% when tested with methyl red. Samples, selected using the asymmetric fringe method, were pressed to a moisture content of 55%. The sample thickness was 3- 4 mm.

In the tanning method we developed [3], the duration of mass transfer of chemical materials into the dermis ranges from 10 to 60 minutes, depending on its thickness. Therefore, determining the rate of mass transfer is complicated by the simultaneous interaction of materials with the structural elements of the dermis. The rate of tanning agent penetration into the dermis was determined using computer processing of a colored dermis section (Fig. 1) [4].

1400

1200 1000

800 600 400 200

0

Thickness

Front Flesh

This method allows to determine precisely the depth of tanning agent penetration and the quantitative assessment of mass transfer under conditions of uneven penetration of the working solution across the thickness of the dermis and interaction of materials with functional groups.

3 Results and Discussion

Environmental issues can be addressed through the use of new technologies that reduce water consumption and eliminate wastewater by completely absorbing the working solutions into the semi-finished product. This eliminates the need for expensive wastewater treatment.

The East Siberian State University of Technology and Management has developed technologies that reduce the negative environmental impact of production and significantly reduce water consumption and wastewater disposal.

These technologies are based on the combination of two or three processes in one, new methods of treating the tanning skin with multi-component systems at a consumption rate of 20-30% of the semi-finished product weight, and the use of high concentrations of working solutions. Moreover, the penetration rate of the working solutions is significantly higher than in aqueous solutions.

The primary factors influencing the new tanning process are the degree of mechanical action and the properties of the tanning agent. Factors such as the degree of tanning loosening and its acidity are secondary. In this case, we propose considering the penetration of tanning agents into the dermis not as a diffusion process, but as a

percolation and diffusion process. Percolation is the predominant factor. Figure 2 shows the percolation of the tanning system 30 minutes after the start of tanning. Moreover, the rate of penetration from the upper dermis is higher than from the lower dermis, as evidenced by the presence of so-called “fingers”. These fingers indicate

that the tanning agent penetrates primarily through the entry points of the hair follicles and the cavities of the sebaceous glands.

Fig 2 – Fragments of visualization of tanning agent

penetration during accelerated tanning chromium compounds in 30 minutes from the start of the process

A distinctive feature of the new technology is not only the intensive permeation of tanning agents throughout the entire thickness of the dermis (30-60 minutes), but also their complete absorption, meaning there are no waste solutions.

The new methods have enabled the development of a new process flow for processing shoe upper leather, offering a number of advantages (Table 1).

Table 1 shows that the new process flow reduces the process cycle time by a factor of 5, reduces the number of processes by 6, reduces water consumption and wastewater disposal by almost 50%, and eliminates dyes and tannins from wastewater.

The new process technology not only provides a number of environmental benefits but also maintains the quality of the finished product and increases the leather yield by 5-10% (Table 2). Furthermore, tanning using the new method can be combined with spread fatliquoring, not just dipping.

Table 1 – Comparative indicators of process flow charts

Duration, h 4–5 20–27

Number of technological processes 6 10

Indicator Experimental

Chromium compound consumption, in % of control

Presence of dyes, tannins, and fats in wastewater

Water consumption per 1,000 kg of raw material, m3

Water disposal per 1,000 kg of raw material, m3 4.60 8.72

Table 2 – Properties of finished leather

Indicator

1 Moisture content, % 10,0-16,0 14,4 14,5

2 Chromic oxide content, %, at least Не менее 3,5 5.3 5,6

3 Mass fraction of substances extractable by organic solvents, %

4 Tensile strength, 10 MPa, at least Не менее 1,3 2.3 1,8

5 Elongation at a voltage 10 MPa,% (except chevrolet and chevrette)

6 Square, %

105,0-110,0 100,0

Conclusion

A new, original process flow diagram for leather processing at the pre-tanning, tanning, and dyeing-fatfinishing stages has been developed. Its advantages are demonstrated: a nearly 50% reduction in water consumption and water disposal, a reduction in the

number of process steps from 10 to 6, and the elimina-

Control Variant

Variant

68 100

None Present

4.90 9.88

Variant

State Standard

of the Russian

Experimental Control

Federation

939-2021

4,0-12,0 8,8 7,0

25,0-55,0 33,0 30,1

tion of dyes, tannins, and fats from wastewater. A new method for determining the mass transfer of tanning agent into the dermis has been developed.

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