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Research article

ASSESSING INDEX OF ACCUMULATED CYTOGENETIC DISORDERS IN WORKERS EMPLOYED IN METALLURGY UNDER EXPOSURE TO ADVERSE OCCUPATIONAL FACTORS

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Metallurgy is a major economic branch in Russia with more than 4000 enterprises operating in it and seventy percent of them being city-forming ones. This study focuses on cytological assessment of the oral mucosa and secretion from the middle meatus mucosa in workers employed in metallurgy.

The aim of this study was to investigate cytological laboratory indicators in workers employed in metallurgy under exposure to adverse occupational factors.

A clinical and diagnostic examination of workers employed at a metallurgical plant in Bashkortostan was performed in 2019–2020; it involved cytological studies of the oral mucosa (buccal epithelium) and the middle meatus mucosa (rhinocytogram). In this study, we applied the Index of cytogenetic disorders accumulation (Iac) that allows for cellular kinetics indicators.

The overall hygienic assessment of working conditions for workers employed at the analyzed metallurgic plant corresponds to the hazard category 3.2–3.3 in accordance with the criteria outlined in the Guide R (harmful, class 2 or 3). The research results revealed cytogenetic disorders of buccal epithelial cells in the workers who had contacts with adverse occupational factors. Low likelihood of cytogenetic disorders was established for 66.67 % of the workers; moderate, 9.2 %; high, 23.81 %. We assessed rhinocytograms of the workers exposed to adverse occupational factors and revealed some signs of allergic inflammation characterized with high eosinophil count.

The research results confirm high significance of diagnostic procedures for developing an algorithm for screening examinations of working population as well as indicators of health disorders under exposure to adverse occupational factors (noise, heating microclimate, industrial dust, gaseous chemicals).

Keywords: *metallurgical production, hygienic assessment of working conditions, adverse occupational factors, Index of cytogenetic disorders accumulation, buccal epithelium cells, rhinocytogram.*

Metallurgy is a major economic branch in Russia with more than 4000 enterprises operating in it and more than seventy percent of them being city-forming ones [1–4]. More than a half million people are employed in the branch. Metallurgic productions rely on complete production cycles; this involves using multiple technological processes, different temperature regimes, binding substances and catalysts. Despite massive modernization which is now taking place in the industry, workers employed in it are still exposed to variable adverse occupational factors. They include noise, heating microclimate, industrial dusts, flammable, explosive and poisonous substances, vibration, ultra-

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sound, electromagnetic radiation as well as substantial physical loads and work in night shifts [1, 5–7]. Domestic studies have confirmed a substantial role that belongs to adverse occupational factors at metallurgic production in developing pathologies of various organs and systems [8, 9], including upper respiratory mucosa. They can progress latently and become a factor that induces various respiratory diseases [10].

At present, it is becoming more and more vital to search for the most informative physiological, biochemical, immunologic and other criteria to estimate effects produced by harmful factors [11, 12].

Rhinocytogram (RCG) studies that involve microscopic examination of imprint smears taken off the nasal mucosa are a simple atraumatic procedure for estimating the state of the respiratory mucosa [13, 14]. RCG provides an insight into the condition of the epithelial tissue in the upper airways and leukocyte occurrence as well as tentatively estimates microflora [15, 16].

Micronuclei assay of the buccal epithelium is a procedure for estimating diseases and processes associated with DNA damage induction; it is considered an effective biomarker [17]. This assay is becoming popular with researchers due to its low invasiveness in cell sampling, simple preparation and storage procedures. All this makes the buccal macronuclei assay an ideal option to conduct molecular-epidemiological examinations [18–20].

Some studies address using the buccal macronucleus assay at productions that involve exposure to formaldehyde, pesticides, and cytostatics; at iron and chromium productions; copper-smelting plants; clothing manufacture; in microbiological industry; auto repair shops etc. [21]. Still, we have not been able to find any studies with their focus on examining the buccal micronuclei assay and imprint smears taken off the nasal mucosa (rhinocytogram) of workers employed in metallurgy.

The relevance of this study is evidenced by detected pre-pathological and pathological conditions; they make it possible to diagnose severity of an occupational or a work-related disease and predict its possible clinical course.

In this study, we aimed to investigate cytological laboratory indicators in workers employed in metallurgy under exposure to adverse occupational factors.

Materials and methods. To achieve our aim and solve the research tasks within this study, we conducted a complex clinical and diagnostic examination of workers employed at a metallurgical plant in 2019–2020; the plant was located in the Republic of Bashkortostan. Laboratory indicators were analyzed relying on data of a periodical medical examination (PME). It was performed in conformity with the Order by the RF Labor Ministry No. 988n, the RF Public Healthcare Ministry No. 1420n issued on December 31, 2020[1]. The test group was made up of workers with various occupations employed at the analyzed enterprise; their occupational activities were likely to involve exposure to harmful occupational factors. We used the following criteria to include workers into the test group and to sample biomaterials: a chronic disease (with exacerbation over the last 12 months) or acute diseases (2 or more over the last 12 months) of the respiratory organs in a case history; exposure to predominantly fibrogenic aerosols at a workplace. The reference group included workers employed at the same plant who were not exposed to harmful production factors. Workers' average age was 53.76 ± 1.26 years and their average work records at the plant equaled 25.66 ± 1.22 years. Both groups were comparable as per age and sex; all the analyzed workers had long work records.

[1] Ob utverzhdenii perechnya vrednykh i (ili) opasnykh proizvodstvennykh faktorov i rabot, pri vypolnenii kotorykh provodyatsya obyazatel'nye predvaritel'nye meditsinskie osmotry pri postuplenii na rabotu i periodicheskie meditsinskie osmotry: Prikaz Mintruda Rossii i Minzdrava Rossii ot 31 dekabrya 2020 goda № 988n/1420n [On Approval of the list of harmful and (or) hazardous occupational factors and works that require mandatory preliminary medical examinations prior to recruitment and periodical medical examinations: The Order by the RF Labor Ministry and RF Public Healthcare Ministry issued on December 31, 2020 No. 988n/1420n]. *KODEKS: electronic fund for legal and reference documentation*. Available at: https://docs.cntd.ru/document/573473071 (June 27, 2022) (in Russian).

We analyzed the results obtained by laboratory and instrumental control. It included examining air samples taken in closed premises, noise measurements, microclimate at workplaces, and artificial lighting. All the tests and measurements were performed by the Testing Laboratory of the Center for Hygiene and Epidemiology in the Republic of Bashkortostan. Hygienic assessment of working conditions relied on the results of workplace evaluation and industrial control, our own observations of production processes and job descriptions provided by the human resources department of the plant.

Cytological studies involved examining samples of non-keratinized stratified squamous epithelium of the oral cavity mucosa (buccal epithelium) and the middle meatus mucosa. Micronuclei were identified in the buccal epithelium as per the standard described by P.E. Tolbert [22]. We also considered binucleated cells, karyopyknosis, karyorrhexis, and karyolysis. To estimate cellularity of a smear and morphological picture of secretion from the middle meatus mucosa as a whole, we performed thin-section analysis similar to blood leukocyte count. The threshold value was set at 100 and the results were given in %. The count covered epithelium (separately cylindrical, with metaplasia, squamous, with degeneration signs, including "naked nuclei") and leukocytes (neutrophils, eosinophils, monocytes, and lymphocytes). When describing a preparation, we noted the total smear cellularity; it was scarce in case some sporadic cells were identified in the field of vision, moderate in case small groups made of 3–5 cells were identified and multi-cellular if layers or dozens of cells were visible. We estimated how epithelium was located (groups, layers or sporadic cells), signs of degenerative changes in cylindrical epithelium, occurring mucus and microflora (cocci and bacilli).

This procedure makes it possible to identify cellular changes caused by exposure to physical and chemical irritation in secretion from the middle meatus mucosa [23]. Glass slides were examined on Mikmed-5 microscope (Russia) under magnification 10 × 40; 10 × 100.

In this study, we applied a so called index of accumulation of cytogenetic damage (Iac), which considered cellular kinetic indicators [24]. We defined three groups as regards likelihood of risks that cytogenetic damages would occur: low (Iac $\leq$ 2), moderate (2 < Iac < 4) and high likelihood (Iac $\geq$ 4). Laboratory tests were performed only after all the participants gave their informed consent to them in accordance with the ethical principles stated in the Declaration of Helsinki (2000).

The results were analyzed with Statistica 6.0 software; we determined simple mean (M), standard error of the mean (m), and authenticity of the results by using the parametric Student's t-test (t) and the level of significance (p). Age-related causality of health disorders was identified by using the correlation coefficient (r).

Results. Basic occupations employed at the analyzed plant include wire drawers, refractory workers, annealers, automatic cold upsetter operators, cable winding operators etc. The environment tends to change substantially during the whole work shift; temperature grows drastically in warm season and drops in cold one; there is also powerful radiation from heated and smelted metals. Air is heavily polluted with dusts at some production sections, especially where metal is being prepared for further production operations. These processes involve substantial emissions of carbon oxide, fibrogenic aerosols, etc.

Wire drawers are exposed to dusts with silicon dioxide; workplace air at their workplaces also contains elevated levels of di-sodium carbonate. The overall hygienic assessment of working conditions at a wire drawer's workplace ranks them as harmful, the hazard category 3.3.

Refractory workers are exposed to dusts from refractory materials, carbon oxide and their work involves a lot of physical strain. Workplace air contains carbon oxide, fibrogenic aerosols and asbestos-containing dusts in concentrations by several times higher than MPC. The overall hygienic assessment of working conditions at a workplace of a refractor worker who deals with thermal furnace lining ranks them as the hazard category 3.2 (harmful conditions).

Basic work operations performed by annealers over the whole work shift involve exposure to di-iron trioxide and dusts with silicon dioxide (up to 1.5 MPC). The overall hygienic assessment of working conditions at an annealer's workplace ranks them as harmful, the hazard category 3.3.

Automatic cold upsetter operators are exposed to high concentrations of fibrogenic aerosols at their workplaces. The overall hygienic assessment of working conditions at an automatic cold upsetter operator's workplace ranks them as harmful, the hazard category 3.3.

Workplace air at a workplace of a cable winding operator contains plant and animal dusts together with silicon dioxide in levels being by several times higher than permissible ones. The overall hygienic assessment of working conditions at a workplace of a cable winding operator ranks them as the hazard category 3.2 (harmful conditions)

The overall hygienic assessment of working conditions at the analyzed metallurgic plant ranks them as harmful (class 3), the hazard category 2–3, according to the Guide R 2.2.2006-05[2] (table).

The tests revealed cytogenetic damages to the buccal epithelium cells in workers exposed to harmful occupational factors (Figure).

We detected more frequent buccal epitheliocytes with micronuclei in 47.61 % of the examined workers. This value was by two times higher than in the reference group ($p > 0.05$). Morphological signs evidencing impaired proliferation were identified in 7.14 % of the analyzed workers. Signs of cell necrosis were statistically significant ones among indicators of nucleus destruction. Karyolysis as a result of necrotic cell destruction was identified in 35.71 % of the examined workers ($p > 0.05$); it was preceded by occurring perinuclear vacuole or perinuclear vacuolization. Karyopyknosis is considered a natural way of buccal epithelium cellular apoptosis; it was identified in 11.90 % of the examined workers. Cells with karyorrhexis signs were detected in 2.38 % of the examined production workers.

We applied the index of accumulation of cytogenetic damage to calculate likelihood of cytological abnormalities. Low likelihood of cytogenetic damage was identified for 66.67 % of the examined workers; moderate, 9.2 %; high, 23.81 %.

RCG assessment established moderate total cellularity in preparations of workers exposed to harmful occupational factors. Squamous epithelium cells were in groups and in layers and were identified in 52.38 % of the examined workers. Neutrophilia as a sign of non-specific, probably microbial, inflammation was detected in 85.71 % of the examined workers; elevated quantities of cylindrical

Table

Working conditions for workers employed at the analyzed metallurgical plant, ranked as per harmfulness and hazards

Occupation	Harmful factors, hazard category of working conditions					
	Noise	Plant and animal dusts	Chemicals (sanitary-hygienic profile)	Labor hardness	Microclimate in workshops	Overall assessment of working conditions
Wire drawer	3.1	3.1	3.1	3.1–3.2	3.1	3.3
Refractory worker dealing with thermal furnace lining	3.1	3.2	3.1	3.1–3.2	3.1	3.2–3.3
Annealer	3.1	3.1	3.1	3.2	3.1	3.3
Automatic cold upsetter operator	3.1	3.2	3.2	3.2	3.2	3.3
Cable winding operator	3.1	3.1	3.1	3.1–3.2	3.1	3.2

[2] The Guide R 2.2.2006-05. Guide on Hygienic Assessment of Factors of Working Environment and Work Load. Criteria and Classification of Working Conditions (approved by G.G. Onishchenko, the RF Chief Sanitary Inspector on July 29, 2005, became valid on November 01, 2005). *KODEKS: electronic fund for legal and reference documentation*. Available at: https://docs.cntd.ru/document/1200040973 (July 09, 2022) (in Russian).

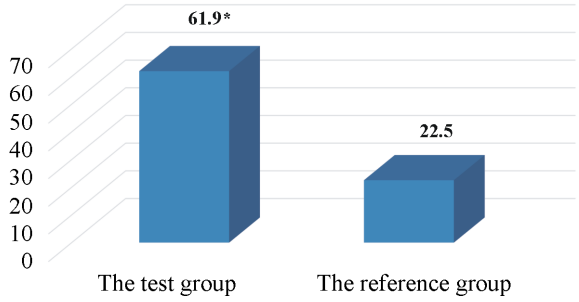

Figure. Cytogenetic damages to the buccal epithelium cells in workers exposed to harmful occupational factors (%): * means differences are authentic ($p < 0.05$)

epithelium, 28.57 %; slight metaplasia in epithelium, 9.52 % of the analyzed workers. Some insignificant quantities of microflora, predominantly cocci, were identified in smears. Some patients had signs of allergic inflammation evidenced by elevated eosinophil quantities in 28.57 % of the examined workers. Cytological preparations of the middle meatus mucosa in the reference group had cylindrical epithelium cells in rare fields of vision (5.00 % of the workers in this group); sporadic squamous epithelium layers and epithelial cells with metaplasia were identified in 15.00 % of the workers in this group.

Discussion. Metallurgic production typically involves emissions of multiple harmful chemicals into workplace air. These chemicals are applied in technological processes or are manufactured by using them and can produce variable effects on the human body. Industrial aerosols make cytogenetically abnormalities in the buccal epitheliocytes of the oral mucosa much more probable thereby moving workers from a group with moderate likelihood of such disorders into a group with high likelihood. Cytological and morphological signs of the process are elevated numbers of cells with impaired proliferation and cells with necrosis signs. By analyzing the index of accumulation of cytogenetic damage, we confirmed cytotoxic effects produced by industrial aerosols. More frequent occurrence of cells with cytogenetic changes in the oral cavity is considered the earliest sign of disrupted cytogenetic homeostasis and a decrease in workers' adaptation resources [25]. Degenerative (dystrophic) changes in the nasal secretion epithelium develop due to cytopathogenic effects produced by microflora, allergens, or chemical aerosols. Other signs of a degenerative process include cilia loss, nucleus and cytoplasm vacuolization, hypochromia, cytoplasm acidophilia, cytoplasm having fuzzy contours up to its complete destruction with 'naked" nuclei occurrence [20].

In this study, we analyzed the data obtained by laboratory tests and examination of workers employed at a metallurgical plant. The analysis established that exposure to industrial aerosols leads to much greater likelihood of developing cytogenetic abnormalities in the buccal epithelium cells and in the epithelial cells of nasal secretion. The research results confirm high significance of diagnostic procedures for developing an algorithm for screening examinations of working population as well as indicators of health disorders under exposure to adverse occupational factors.

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References

1. Egorova A.M., Zheglova A.V., Saarkoppel' L.M. Analiz professional'nogo riska dlya zdorov'ya rabochikh metallurgicheskogo proizvodstva [Analysis of occupational health risks for workers in metallurgical production]. *Analiz riska zdorov'yu 2020 sovmestno s mezhdunarodnoi vstrechei po okruzhayushchei srede i zdorov'yu Rise-2020 i kruglym stolom po bezopasnosti pitaniya: materialy X Vserossiiskoi nauchno-prakticheskoi konferentsii s mezhdunarodnym uchastiem: v 2 t.* In: A.Yu. Popova, N.V. Zaitseva eds. Perm, Perm National Research Polytechnic University Publ., 2020, vol. 2, pp. 142–147 (in Russian).

2. VNII truda. Metallurgiya. Analiticheskaya spravka [Metallurgy. Analytical reference], 2019, 92 p. (in Russian).

3. Kagiyan O.A. Vliyanie gradoobrazuyushchego predpriyatiya na ekonomiku i ekologiyu goroda Lipetska [The influence of the city-forming enterprise on the economy and ecology of the city of Lipetsk]. *Aktual'nye problemy sovremennoi ekonomiki: ot finansovykh i sotsial'nykh institutov k marketing.* St. Petersburg, April 13, 2018, pp. 194–200 (in Russian).

4. Dyagtereva I.V., Sazykina M.Yu., Beschastnova N.V. Strategicheskie zadachi razvitiya metallurgicheskoi otrasli v Respublike Bashkortostan v kontekste rossiiskikh i mirovykh tendentsii [Strategic objectives for the development of the metallurgical industry in the Republic of Bashkortostan in the context of Russian and global trends]. *Teoreticheskaya i prikladnaya ekonomika*, 2016, no. 4, pp. 103–120 (in Russian).

5. Tchebotaryov A.G., Prokhorov V.A. Contemporary work conditions and occupational morbidity in metallurgists. *Meditsina truda i promyshlennaya ekologiya*, 2012, no. 6, pp. 1–7 (in Russian).

6. Vlasova E.M., Shlyiapnikov D.M., Lebedeva T.M. Analysis of changes in characteristics of arterial hypertension occupational risk in workers of nonferrous metallurgy. *Meditsina truda i promyshlennaya ekologiya*, 2015, no. 8, pp. 10–13 (in Russian).

7. Masyagutova L.M., Abdrakhmanova E.R., Bakirov A.B., Gimranova G.G., Akhmetshina V.T., Gizatullina L.G., Gabdulvaleeva E.F., Volgareva A.D., Hafizova A.S. The role of working conditions in the formation of occupational morbidity of workers in metallurgical production. *Gigiena i sanitariya*, 2022, vol. 101, no. 1, pp. 47–52. DOI: 10.47470/0016-9900-2022-101-1-47-52 (in Russian).

8. Zaitseva N.V., Shur P.Z., Klimenko A.R., Ustinova O.Yu., Lebedeva-Nesevria H.A., Kostarev V.G. Hygienic evaluation of risk factors on powder metallurgy production. *Meditsina truda i promyshlennaya ekologiya*, 2011, no. 11, pp. 16–19 (in Russian).

9. Bazarova E.L., Fedoruk A.A., Roslaya N.A., Osherov I.S., Babenko A.G. Assessment experience of occupational risk associated with exposure to industrial aerosols under the conditions of metallurgical enterprise modernization. *ZNiSO*, 2019, vol. 310, no. 1, pp. 38–45. DOI: 10.35627/2219-5238/2019-310-1-38-45 (in Russian).

10. Ryazantsev S.V., Khmel'nitskaya N.M., Tyrnova E.V. Patofiziologicheskie mekhanizmy khronicheskikh vospalitel'nykh zabolevanii slizistoi obolochki verkhnikh dykhatel'nykh putei [Pathophysiological mechanisms of chronic inflammatory diseases of the mucous membrane of the upper respiratory tract]. *Vestnik otolaringologii*, 2001, no. 6, pp. 56–59 (in Russian).

11. Potapov A.I. Hygiene: reality and perspectives. *Zdravookhranenie Rossiiskoi Federatsii*, 2003, no. 3, pp. 3–4 (in Russian).

12. Rakhmanin Yu.A., Revazova Yu.A. Prenosological diagnosis in the environment-human health area. *Gigiena i sanitariya*, 2004, no. 6, pp. 3–5 (in Russian).

13. Appel'gans T.V., Chinyaeva N.S., Makhov V.A., Kuz'mina L.V. Znachimost' morfologicheskogo issledovaniya v diagnostike rinosinusitov [The significance of morphological research in the diagnosis of rhinosinusitis]. *Vrach-aspirant*, 2006, no. 3, pp. 208–213 (in Russian).

14. Barkhina T.G., Gusniev S.A., Gushchin M.Yu., Utesheva V.A., Chernikov V.P. Clinical and morphological characteristics of various forms of rhinitis. *Morfologicheskie vedomosti*, 2017, vol. 25, no. 2, pp. 14–20. DOI: 10.20340/mv-mn.17(25).02.02 (in Russian).

15. Zhuravskaya N.S., Vitkina T.I., Krukovskaya E.A., Nastavsheva T.A. Metod mazkov-otpechatkov so slizistoi nosa v diagnostike zabolevanii organov dykhaniya [The method of smear-imprints from the nasal mucosa in the diagnosis of respiratory diseases]. *Klinicheskaya laboratornaya diagnostika*, 2002, no. 2, pp. 40–42 (in Russian).

16. Zimina V.A., Ptitsyna A.I., Sokolov I.I. Rinotsitogramma – diagnosticheskoe znachenie laboratornogo issledovaniya [Rhinocytogram – diagnostic value of laboratory research]. *Fundamental'nye problemy nauki: sbornik statei Mezhdunarodnoi nauchno-prakticheskoi konferentsii: v 2-kh chastyakh*. Ufa, Aeterna LLC, 2016, pt 2, pp. 158–160 (in Russian).

17. Hopf N.B., Bolognesi C., Danuser B., Wild P. Biological monitoring of workers exposed to carcinogens using the buccal micronucleus approach: A systematic review and meta-analysis. *Mutat. Res. Rev. Mutat. Res.*, 2019, vol. 781, pp. 11–29. DOI: 10.1016/j.mrrev.2019.02.006

18. Fenech M., Holland N., Zeiger E., Chang W.P., Burgaz S., Thomas P., Bolognesi C., Knasmueller S. [et al.]. The HUMN and HUMNxL international collaboration projects on human micronucleus assays in lymphocytes and buccal cells – past, present and future. *Mutagenesis*, 2011, vol. 26, no. 1, pp. 239–245. DOI: 10.1093/mutage/geq051

19. Dhillon V.S., Aslam M., Husain S.A. The contribution of genetic and epigenetic changes in granulosa cell tumors of ovarian origin. *Clin. Cancer Res.*, 2004, vol. 10, no. 16, pp. 5537–5545. DOI: 10.1158/1078-0432.CCR-04-0228

20. Krishna L., Sampson U., Annamala P.T., Unni K.M., Binukumar B., George A., Sreedharan R. Genomic Instability in Exfoliated Buccal Cells among Cement Warehouse Workers. *Int. J. Occup. Environ. Med.*, 2020, vol. 11, no. 1, pp. 33–40. DOI: 10.15171/ijoem.2020.1744

21. Sycheva L.P. Biological value, scoring criteria and limits of a variation of a full spectrum karyological indexes of exfoliated cells for estimation of human cytogenetic status. *Meditsinskaya genetika*, 2007, vol. 6, no. 11 (65), pp. 3–11 (in Russian).

22. Tolbert P.E., Shy C.M., Allen J.W. Micronuclei and other nuclear anomalies in buccal smears: methods development. *Mutat. Res*., 1992, vol. 271, no. 1, pp. 69–77. DOI: 10.1016/0165-1161(92)90033-i

23. Gelardi M., Tapaculo M., Cassano M., Besozzi G., Fiorella M.L., Calvario A., Castellano M.A., Cassano P. Epstein-Barr virus induced cellular changes in nasal mucosa. *Virol. J.*, 2006, vol. 3, pp. 6. DOI: 10.1186/1743-422X-3-6

24. Sycheva L.P. Cytogenetic monitoring for assessment of safety of environmental health. *Gigiena i sanitariya*, 2012, vol. 91, no. 6, pp. 68–72 (in Russian).

25. Deryugina A.V., Ivashchenko M.N., Ignatiev P.S., Samodelkin A.G., Belov A.A., Gushchin V.A. The evaluation of genotoxic effects in buccal epithelium under disorders of adaption status of organism. *Klinicheskaya laboratornaya diagnostika*, 2018, vol. 63, no. 5, pp. 290–292. DOI: 10.18821/0869-2084-2018-63-5-290-292 (in Russian).

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