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Environmental Contamination and Male Reproductive Health in Kyrgyzstan: Clinical Assessment of Sexual Function and Spermatogenic Impairment

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ABSTRACT

Male reproductive health is becoming affected by environmental degradation, however, most of the studies are focusing mainly on semen parameters with a lack of attention to sexual function and functional outcomes beside semen parameters. Integrated evaluations of sexual and reproductive dysfunctions in environmentally exposed populations remain limited; this study assesses them using a clinical–functional ICF framework. A study of a cross-sectional survey was performed among 216 men aged between 25-45 years of age who are residing for at least 5 years in the different parts of the Kyrgyz Republic where environmental conditions are different. Participants were separated in four groups (an environmentally favorable control group and three exposure groups, characterized by pesticide exposure, heavy metal contamination, and radionuclide exposureSexual function was assessed using IIEF, and reproductive function through semen analysis. Men in contaminated regions showed significantly reduced erectile and orgasmic function ($p < 0.05$). Semen analysis indicated a significant increase in reproductive parameters in all the exposure groups, with a decrease in sperm concentration, reduction of progressive motility and velocity, reduction of morphologically normal and viable spermatozoa, and increasing proportion of immature germ cells ($p < 0.05$). The greatest impairments were evident in the case of men exposed to the pesticides and heavy metals. The environmental disadvantage is linked with a dual impairment of sexual function and spermatogenesis in the men of reproductive age. Application of the ICF framework highlights sexual dysfunction as an environmentally relevant indicator of reproductive health impairment.

Keywords: *International Classification of Functioning (ICF), Environmental factors, Reproductive system function, Sexual functioning, Male fertility*

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INTRODUCTION

Male reproductive health is now increasingly understood to be a sensitive indicator of environmental health, especially in chronically ecologically stressed regions. Over the past few decades, a multitude of studies have communicated declining characteristics in semen quality of men living in environmentally unfavourable settings, such as a decrease in sperm concentration, motility, viability, and normal morphology (Gallo *et al*., 2020). These changes are of special concern as they relate to the direct impact on male fertility potential and because they may indicate a deeper functional disturbance of the reproductive system. Environmental pollutants, including pesticides, heavy metals, and radionuclides, are widely distributed in agricultural, industrial, and post-industrial regions (Krzastek *et al*., 2020). Chronic exposure to these factors has been linked to impaired spermatogenesis, inflammatory alterations of the male reproductive tract, and structural damage of the germinal epithelium (Li *et al*., 2024). Most clinical and epidemiological studies involving environmental reproductive toxicity focus mostly on laboratory-based semen parameters, which, whilst essential, do provide a partial picture of the health of male reproduction (Defeudis *et al*., 2026).

Sexual function is another aspect of male reproductive capacity that has been understudied. Erectile and orgasm function depend upon the coordinated integrity of neurovascular function, reproductive organs, as well as general somatic health (Azadzoi *et al*., 2013). Disturbances in sexual function may occur concomitantly with poor semen quality and could have a direct impact on reproductive behavior and fertility outcome. However, cases of sexual dysfunction are rarely evaluated in comparison to semen parameters in research investigating the effects of environmental exposure, and thus far, this has left a patchwork understanding of impairment of reproductive health (Chung *et al*., 2024). An integrated clinical-functional perspective is therefore needed to better characterize the impact of the environmental disadvantage on male reproductive health (Kapoor *et al*., 2025). The International Classification of Functioning, Disability and Health (ICF) provides an appropriate conceptual framework for such an approach. Within this model, environmental pollutants are an environmental factor that leads to the impairments of body functions and structures, which may be in the form of decreased semen quality and sexual dysfunction, ultimately affecting the ability to participate in reproductive activity and participation (Vargus-Adams & Majnemer, 2014; Oralbekova *et al*., 2021).

In this context, men living in environmentally contaminated regions may suffer not only from laboratory detectable abnormalities of the spermatogenesis process but also clinically relevant impairment of the sexual function. Evaluating these outcomes together provides for a more complete evaluation of reproductive system functioning and insight into the functional importance of the environmentally mediated damage. This study aims to evaluate sexual and reproductive dysfunctions in men of reproductive age who are living in areas with different types of environmental exposure. Using standardized assessment of sexual function and detailed semen analysis, this study aims to determine the patterns of functional impairment that are associated with exposure to pesticides, heavy metals, and radionuclides and interpret this finding in a clinical-functional context. Such an approach may contribute to achieving a better understanding of the real-life consequences of environmental disadvantage on male reproductive health and provide insights for future prevention and clinical approaches.

MATERIALS AND METHODS

Study design and participants

A cross-sectional clinical study was performed to evaluate the sexual and reproductive functioning of men living in different regions with varying environmental conditions in Kyrgyzstan. The data were gathered through a single examination protocol during the study. The investigation involved 216 reproductive-aged men (25-45 years) who had lived permanently in their respective regions for at least five years. Participants were assigned to different groups according to the main environmental features of their residential area.

Control group: men living in environmentally favorable regions (n = 62)

Pesticide exposure group: residents of agricultural areas with intensive pesticide use (n = 54)

Heavy metals exposure group: residents of industrial regions with documented heavy metal contamination (n = 52)

Radionuclide exposure group: residents of areas with increased background radiation (n = 48)

Inclusion criteria were male sex, age between 25 and 45 years, permanent residence in the study area for at least five years, and provision of written informed consent. Exclusion criteria included acute inflammatory diseases of the urogenital system, confirmed genetic causes of infertility, oncological diseases, and severe decompensated somatic pathology.

Assessment of sexual function

The International Index of Erectile Function (IIEF) was used to measure sexual function. This is a validated multidimensional questionnaire that is widely used in clinical and epidemiological studies. For this study, only two functional domains, i.e., erectile function and Orgasmic function, were considered. Standard scoring procedures were followed for calculating the domain scores. Lower scores indicate more severe sexual dysfunction. The IIEF questionnaire was completed by participants themselves following standardized conditions.

Assessment of reproductive function

Reproductive function was assessed by semen analysis to confirm the fertility of the individuals under test. Semen samples were obtained through sexual abstinence and were examined based on the standardized methods of the industry. The parameters taken for the analysis comprise: Spirit volume, Number of sperm (million/mL), Percentage of forward-moving sperm, Speed of motile sperm (mm/min), Percentage of living spermatozoa, Percentage of spermatozoa with normal morphology, Percentage of cells from round spermatogenesis (immature), Concentration of leukocytes in semen (million/mL). Only aggregated semen parameters relevant to the objectives of the study were considered. Extended semen characteristics and advanced diagnostic tests were not included in the present analysis.

Functional interpretation within the ICF framework

They used the conceptual framework of the International Classification of Functioning, Disability and Health (ICF) to interpret the study findings. The situation of the environment was taken as one of the environmental factors that has an impact on a person's health status. They viewed changes in sexual function and semen parameters as disorders of the body functions and structures of the reproductive system; thus, they could result in limitations in reproductive activity and participation. The ICF framework was used as a model of analysis and interpretation without systematic coding.

Statistical analysis

The statistical analysis was carried out using non-parametric methods. Quantitative variables are reported as mean ± standard error (M ± m). The variation in groups was checked by the Mann–Whitney U test for continuous variables and the chi-square (χ^2) test for categorical variables. A difference was regarded as statistically significant if the p-value was less than 0.05.

Ethical considerations

The study was reviewed and approved by the Ethical Committee and Institutional Review Board of Osh State University under protocol number 01/26.03.2024. The study was conducted in accordance with the principles of the Declaration of Helsinki (World Medical Association, 2013). All participants provided written informed consent prior to inclusion in the study. Participant anonymity and data confidentiality were maintained throughout the research process.

RESULTS AND DISCUSSION

Patterns of sexual function impairment by environmental exposure group

Assessment using the International Index of Erectile Function (IIEF) showed significantly poorer erectile and orgasm function in men living in environmentally disadvantaged areas compared to controls ($p < 0.05$). The greatest decline was observed in those exposed to pesticides and heavy metals, while radionuclide exposure showed a smaller but still significant impairment. Importantly, sexual dysfunction was widespread. diminished erectile function was regularly accompanied by diminished orgasmic capacity, indicating a general sexual dysfunction. This suggests that environmental exposure affects sexual function overall rather than just certain parts. Overall, the findings show that males in environmentally disadvantageous areas had far worse sexual function than their peers in environmentally favorable places. These findings show that environmentally exposed people have sexual dysfunction and give a functional context for reproductive deficits seen in follow-up research.

Changes in ejaculation traits and inflammatory markers

According to the results of the analysis of the parameters of ejaculation, it was found that the parameters of ejaculation of men exposed to adverse environmental factors are significantly different from those of the control group, which is a sign of violations of the functional state of the male reproductive system. The parameters assessed were ejaculate volume, sperm concentration, and leukocyte count, and all showed different but related patterns of change across exposure groups.

The average ejaculate volume of the control group, as shown in **Table 1**, was 2.9 ± 0.3 mL, which is consistent with reference values of men of reproductive age. In contrast, a decrease in ejaculate volume was observed in all the environmentally exposed groups. The largest reduction was observed in men living in areas of secession, where ejaculate volume was reduced to 2.0 ± 0.4 mL, which is a statistically significant difference compared with the controls ($p <0.05$). Men exposed to heavy metals and pesticides also had decreased ejaculate volumes (2.1 +/- 0.6 mL and 2.3 +/- 0.4 mL, respectively), suggesting a negative effect of environmental factors on the secretory function of the reproductive glands. Sperm concentration showed a greater and more consistent decrease amongst all exposure groups. While the control group revealed a mean of 65.4±11.3 million/mL concentration of sperm, values were significantly less in the exposure groups. The greatest reduction was seen in the radionuclide exposure group (35.2 ± 8.4 million/mL), followed by the pesticide (42.5 ± 14.4 million/mL) and heavy metal (48.3 ± 10.5 million/mL) groups. All reductions were statistically significant as compared with the control group ($p <0.05$) **(Table 1)**.

Table 1. Ejaculate volume, sperm count, and white blood cell count in the spermogram of male subjects from different regions of Kyrgyzstan (M±m)

Indicators	Group 1 Control (n=62)	Group 2 (Pesticides) (n=54)	Group 3 (TM) (n=52)	Group 4 (PH) (n=48)
Ejaculate volume, ml	2,9±0,3	2,3±0,4	2,1±0,6	2,0±0,4*
Number of spermatozoa in 1 ml of ejaculate (million/ml)	65,4±11,3	42,5±14,4*	48,3±10,5*	35,2±8,4*
The number of white blood cells (million/ml) in the spermogram	is 0.42±0.07	1.21±0.12*	1.13±0.22*	1.30±0.14*

Note: * - p <0.05 compared to gr. 1 (cr. Mann-Whitney)

Environmentally exposed men showed reduced ejaculate volume and sperm concentration, along with significantly higher semen leukocyte levels (1.13–1.30 vs. 0.42 million/mL in controls; $p < 0.05$), indicating inflammation. Overall, environmental exposure is associated with impaired semen quality and inflammatory changes, reflecting complex reproductive dysfunction affecting both spermatogenesis and accessory gland function.

Disturbances of sperm motility and kinetic performance

Evaluation of sperm motility and kinetic parameters showed a great impairment of sperm function in the men subjected to bad environmental conditions. The velocity of motile spermatozoa and the percentage of progressively motile sperm were consistently lower in all the exposure groups than in controls.

In the control group, the average velocity of motile spermatozoa was 2.98 (±0.14) mm/min, showing the maintenance of the kinetic activity. In contrast, men exposed to pesticides showed a significant decrease in sperm velocity with 2.01 ± 0.27 mm/min, the most pronounced effect of the exposure groups ($p <0.05$). Men who lived in areas affected by heavy metals and radionuclides also showed significantly lower velocities of 2.29 ±0.16 mm/min and 2.34±0.21 mm/min, respectively ($p <0.05$). A similar trend was seen for the proportion of more and more motile spermatozoa as described in **Table 2** (see table). In the control group, the proportion of progressively motile sperm was 66.2±5.4% of the ejaculate.

The proportion of this decreased significantly in all exposure groups. At the pesticide exposure group, the percentage was at its lowest (44.6 ± 6.1%), which was followed by heavy metal (48.3 ± 6.0%) and radionuclide (53.2 ± 4.4%) groups. All the differences at the $p <0.05$ level were statistically significant when compared with the control group. The simultaneous decrease in sperm velocity and progressive motility reveals a decline in the spermatozoa's functional competence along with less isolated changes in movement patterns. Considering that during pesticide and heavy metal exposure, the most serious damage to spermatozoa was observed. This thus suggests that the severity of kinetic disturbances may vary based on the type of environmental exposure. The results of this study demonstrate that an environmental disadvantage is one of the factors associated with a major drop in sperm kinetic performance, which is a key factor of male fertility potential. The diminished motility and speed will lower the spermatozoa's capacity to function and also aid in explaining the overall reproductive pattern impairment in exposed groups as shown in **Table 2** with Kinesiogram parameters.

Table 2. Kinesiogram parameters in ymale subjects-residents of different regions of Kyrgyzstan (M±m)

Indicators	Group 1 control (n=62)	Group 2 (Pesticides) (n=54)	Group 3 (TM) (n=52)	Group 4 (PH) (n=48)
Speed of movement of mobile spermatozoa, mm / min	2,98±0,14	2,01±0,27*	2,29±0,16*	2,34±0,21*
Percentage of progressively mobile sperm in the ejaculate, %	66,2±5,4	44,6±6,1*	48,3±6,0*	53,2±4,4*

Note: * - p <0.05 compared to gr. 1 (cr. Mann-Whitney)

Changes in sperm viability, morphology, and maturation processes

Assessment of sperm-rated parameters such as viability, morphological normality, and the presence of immature germ cells showed substantial changes in men who had been exposed to unfavorable environmental conditions. The above indicators represent a dictionary look at the functionality of spermatogenesis and the quality of spermatozoa on the molecular level. In the control group, the percentage of viable sperm cells was quite high at 98.6 ± 2.0% on average, which shows preservation of cell membrane integrity. On the contrary, all the groups that were exposed environmentally showed a statistically significant decrease in sperm viability. The group that was exposed to heavy metals had the lowest viability (78.7 ± 5.2%), the next was the pesticide group (80.3 ± 4.5%), and finally, the radionuclide group (84.1 ± 3.9%) (p <0.05). Morphological examination showed that the decline was even more significant. In the control group, the percentage of spermatozoa with normal morphology was 7.2 ± 0.3%, while the exposure groups had more than half of this value. The heavy metal exposure group had the lowest percentage of normal forms at 2.4 ± 0.6%, followed by the radionuclide exposure group at 2.8 ± 0.5% and the pesticide exposure group at 3.2 ± 0.8%. All of these values were significantly reduced compared to the control group (p <0.05).

Simultaneously, the percentage of immature spermatogenesis cells markedly increased after exposure to different toxicant groups **(Figure 2)**. The control group, on average, had a value of 1.2 ± 0.22%, whereas the exposed groups had values of 2.6 ± 0.5% to 3.3 ± 0.4%, which is indicative of a two- to threefold increase (p <0.05). The determination of normal sperm maturation processes was, therefore, disrupted. Altogether, these findings provide evidence that exposure to environmental factors has been deteriorating sperm cell viability, producing serious morphological abnormalities in sperm cells, and also altering the development of germ cells. These alterations indicate that the spermatogenic processes are deeply disturbed and, therefore, the reproductive system dysfunction in men environmentally exposed is further demonstrated and characterized well in **Table 3**.

Table 3. Assessment of sperm viability and morphology in male subjects from different regions of Kyrgyzstan (M±m)

Indicators	Group 1 control (n=62)	Group 2 (Pesticides) (n=54)	Group 3 (TM) (n=52)	Group 4 (PH) (n=48)
Proportion of viable spermatozoa, %	98,6±2,0	80,3±4,5*	78,7±5,2*	84,1±3,9*
Proportion of normal forms of spermatozoa according to the results of the morphology study	7,2±0,3	3,2±0,8*	2,4±0,6*	2,8±0,5*
Proportion of immature spermatogenesis cells	1,2±0,22	2,6±0,5*	3,3±,1*	2,8±0.9*

Note: * - p <0.05 compared to gr. 1 (cr. Mann-Whitney)

Microscopic semen morphology in relation to environmental exposure

Microscopic examination of the semen samples revealed different pathological patterns specific to the type of exposure that work hand in hand with the spermogram quantitative results and visually confirm spermatogenic disruption induced by environmental factors. Semen samples from men in pesticide-exposed agricultural areas showed a significant increase of leukocytes in the seminal fluid, the condition thus being consistent with leukocytospermia **(Figure 4)**. The microscopic field showed dense accumulations of round inflammatory cells that were interspersed with spermatozoa, thus confirming a chronic inflammatory environment within the male reproductive tract. The elevated leukocyte levels support an inflammatory, oxidative mechanism underlying sperm dysfunction in pesticide-exposed men. In contrast, heavy metal exposure showed immature germ cells and structurally abnormal sperm, indicating disrupted spermatogenesis and impaired Sertoli cell function.

The micrograph of the sample with oligospermia **(Figure 3)** (associated with heavy metal exposure) demonstrated a distinctive pathological profile. The photomicrographs revealed a very low density of spermatozoa in the field of view, and the few spermatozoa found were weak in motility and showed abnormal morphology. The microscopic reduction in sperm concentration correlates with the statistically significant decline in sperm counts in this particular exposure group and points out the extensive damage due to heavy metal toxicity on spermatogenic output and sperm survival.

The most profound morphological change was seen in sperm samples from men living in an environment contaminated with radionuclides. Here, the fields were generally characterized by the neuter of spermatozoa, which is practically consistent with azoospermia **(Figure 1)**. Very few or no mature sperm cells were seen in the samples, evidencing an extreme impairment of spermatogenesis that probably reflects probably long lasting injuries to the germinal epithelium and stem cell compartments. This advanced phenotype goes well with the quantitatively lowest sperm concentrations in this group and hence indicates that the reproductive system may irreversibly suffer from chronic low-dose radiation exposure.

These microstructural changes align with quantitative findings, highlighting pollutant-specific pathological patterns in semen. They indicate structural and functional disruptions in spermatogenesis, inflammation, and sperm maturation. Within the International Classification of Functioning framework, these alterations represent impairments in reproductive structures contributing to reduced sexual and reproductive function.

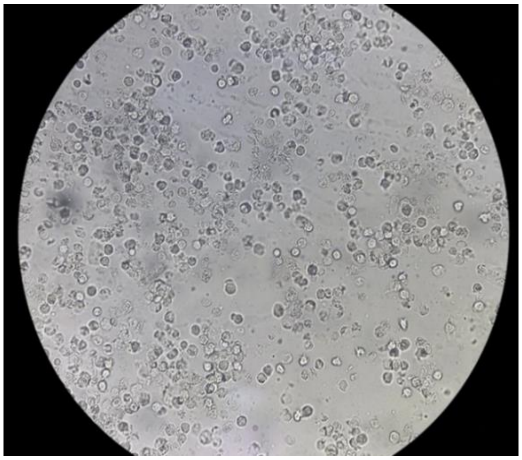

Figure 1. Azoospermia – radionuclide exposure. Microscopy showing absence or near absence of spermatozoa, indicating severe spermatogenic failure.

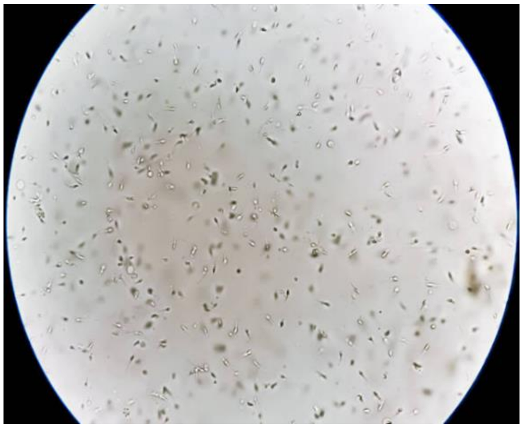

Figure 2. Juvenile cells – heavy metal exposure. Microscopic field showing elevated numbers of round immature spermatogenic cells consistent with disrupted maturation.

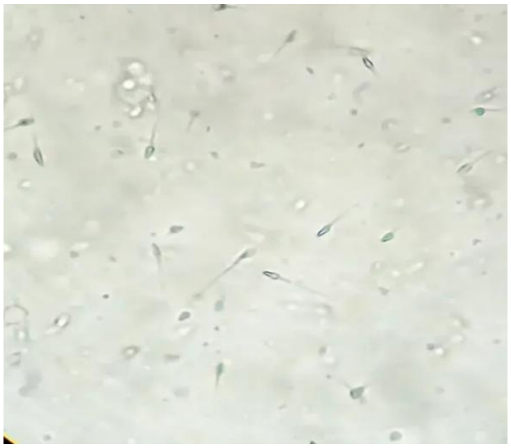

Figure 3. Oligospermia – heavy metal exposure. Reduced sperm density within the visual field, corresponding to decreased sperm concentration.

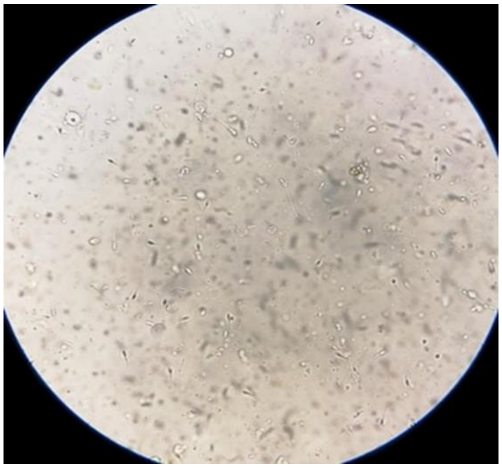

Figure 4. Leukocytospermia – pesticide exposure. Semen microscopy demonstrating increased leukocytes among spermatozoa in men from pesticide-exposed regions.

Principal findings of research report

Men living in environmentally unfavorable areas show consistent, multifaceted reproductive impairment, with both reduced sexual function and poor semen quality. These include decreased sperm concentration, motility, viability, abnormal morphology, and increased immature germ cells across all exposure types (pesticides, heavy metals, radionuclides), suggesting a shared vulnerability to ecological stress. The most severe effects were seen with pesticides and heavy metals, indicating possible exposure-specific impacts.

Comparison using recent studies

The observed decline in the quality of semen among environmentally exposed men is in line with results from recent studies on an international level. Skakkebaek and others (2024) and Levine and others (2024) showed continuing losses in sperm concentration and motility around the globe, especially where there is industrial and agricultural pollution. Similar decreases in the sperm count and quality parameters of progressive motility related to the use of pesticides were reported by Hu *et al.* (2024) and Radwan *et al.* (2024). Heavy metal exposure has been causally associated on several occasions with impaired spermatogenesis and sperm morphology. Di Nisio *et al*. (2024) showed that chronic exposure to cadmium and lead induces disturbance in germinal epithelium integrity, sperm maturation; the results are similar to the results of the increased proportion of immature germ cells noted in the current study. Likewise, Rodprasert *et al*. (2024) found the presence of a marked reduction of sperm viability and motility in the men living in the industrial-contaminated areas. Radiation-related reproductive effects are less extensively studied, but recently, Toppari *et al*. (2024) and Virtanen *et al*. (2024) proved that chronic exposure to low doses of radiation is related to low sperm concentration and damaged tissue with altered kinetic parameters that were similar to our study in the population of radionuclide-exposed. Unlike many studies in the past, the current investigation was conducted while at the same time measuring sexual function. This integrated approach is supported by emerging evidence. Chen *et al*. (2024) and Belladelli *et al*. (2024) found that a vicious cycle between erectile dysfunction and impaired semen parameters occurred, and suggested that the occurrence of erectile dysfunction might be indicative of an underlying systemic and reproductive pathology. Our findings expand these observations to populations exposed to the environment and establish evidence of sexual dysfunction as just one of a more general picture of reproductive impairment**.**

Possible mechanisms of pathophysiology

Although the hormonal and molecular markers were not directly measured in this study, a number of mechanisms may be plausible for the observed results. Oxidative damage affecting sperm in membrane integrity, mitochondrial function, and DNA stability causes low motility, low viability, and abnormal morphology according to Aitken *et al*. (2024) and Burke *et al*. (2024). Inflammatory mechanisms would also seem to have a significant role. The higher levels of leukocyte concentration recorded in the semen samples of the exposed groups indicate the existence of chronic inflammatory processes in the male reproductive tract. Green *et al*. (2024) showed that inflammation worsens oxidative damage and disrupts sperm maturation, which could be the reason for finding a higher percentage of immature germ cells in this study. Sexual dysfunction may result from parallel processes. Neurovascular control of erectile response and ejaculation reacts sensitively, in regard to endothelium damage, oxidative stress, and inflammatory signaling. Nassan *et al*. (2024) and Assidi *et al*. (2024) have suggested that impaired neuronal and vessel biology pathways involved in sexual function may occur due to environmental toxicants, with no striking evidence of hormonal dysfunctions.

Integration within the model of the ICF

A strength of the current research is the interpretation of results in terms of the International Classification of Functioning, Disability and Health (ICF) framework. From this perspective, the environmental pollutants represent adverse environmental factors that trigger a chain reaction of functional impairments. This functional chain has been highlighted in the radical conceptual analyses recently undertaken by WHO-ICF Working Group *et al*. (2024) and Vrijheid *et al*. (2024), who advocate a shift from investigations into isolated biomarkers towards focusing on functional outcomes more indicative of in 'real life' consequences. By showing the coexistence of sexual dysfunction and impaired spermatogenesis, the current study provides a novel recognition of sexual function in terms of clinical relevance and functional significance as a marker of reproductive system health. Within the framework of the ICF, sexual dysfunction can be an initial or synthesizing expression of environment-mediated reproductive disadvantage rather than the secondary or non-satisfying expressions of the disorder.

Clinical and public health implications

The results of this study have significant implications in both the clinical practice and environmental health policy areas. Routine evaluation of the reproductive health of males in environmentally burdened areas should include assessment of sexual function as well as semen analysis. Early detection of functional impairments shall enable early intervention and warning of risks. From the public health standpoint, these findings highlight the importance of preventive interventions against environmental exposure and the protection of reproductive health. As it is emphasized by Skakkebaek *et al*. (2024) and Rodprasert *et al*. (2024), male reproductive health can be a sensitive measure of population-level environmental risk.

Future recommendations

Incorporating the male reproductive health into environmental health policy

Environmental health policies should explicitly include male reproductive health as one of the outcomes of ecological risk assessment. Establishing mandatory reproductive health surveillance in ecologically burdened regions would allow us to detect early on if an adverse trend is emerging and support evidence. Schubert, Such an approach would increase the link between environmental monitoring and protection of the population's health (Ahbab *et al*., 2017; Fucic *et al*., 2021).

Development of focal screening and surveillance programmes

To bring this proposal into policy recommendations, public health authorities should develop specific screening programs directed at men living in areas where environmental contamination occurs. Periodical screening may enable early diagnosis of subclinical dysfunction before irreparable damage to reproduction is made. Surveillance data obtained by these programs would also provide useful epidemiological evidence for tracking long-term effects of environmental exposure at the population level (Babatunde *et al*., 2022; Donato *et al*., 2023).

Use of an integrated clinical assessment model

Clinical practice should progress closer to an integrated model of male reproductive health assessment, which takes into consideration the history of environmental exposure alongside the clinical and laboratory findings. Sexual dysfunction should be both a quality-of-life issue and possibly a marker of reproductive system impairment (Constantin *et al*., 2022; Mojsak *et al*., 2022; Sugimori *et al*., 2022; Kajanova & Badrov, 2024; Lee & Ferreira, 2024; Umarova *et al*., 2024). A multidisciplinary approach by andrologists, urologists, occupational health, and primary care physicians is important for comprehensive management of the patient (Alam *et al*., 2022; Tesarik, 2025).

Development of mechanistic and longitudinal research

Future studies should prioritize longitudinal studies and prospective observational studies that can elucidate cause-and-effect relationships between the environment and male reproductive dysfunction. Individual-level exposure assessment by biomonitoring should be stressed for better accuracy and less exposure misclassification (Siddiqui *et al*., 2022; Kaltsas *et al*., 2025).

Expanded application of the ICF framework to reproductive health research

The International Classification of Functioning, Disability and Health should be used more broadly as a unifying framework in environmental and reproductive health research. Future studies should operationalize ICF domains in order to systematically make links between the environmental factors and impairments of body functions, activity limitations, and participation restrictions related to sexual and reproductive life (Syaifudin *et al*., 2018; Siddiqui *et al*., 2023).

CONCLUSION

This study shows that living in environmentally unfavourable conditions is linked to a consistent and clinically significant impairment of male reproductive health. Men exposed to pesticides, heavy metals, and radionuclides showed not only a significant deterioration of the quality of semen, but also parallel disturbances of the sexual function, both in the erectile and orgasm sphere. The concordance of these changes suggests that environmental exposure has a generalized effect on the male reproductive system and is not restricted to isolated laboratory abnormalities but has a functional consequence. The findings demonstrate that the impairments of spermatogenesis are associated with impaired sexual functioning and that the pathophysiology of spermatogenesis and sexual functioning may be shared rather than independent clinical conditions. At the same time, the steady decline in sexual function calls for an updated consideration of functional capacity in addition to biological ones in relevant evaluations of reproductive health in environmentally exposed populations. Application of the International Classification of Functioning in relation to disability and health gives the integrated interpretation of these results. Environmental pollutants are negative environmental factors leading to impairments in the reproductive body functions and structures, which in turn, result in limitations in sexual and reproductive activity (Alhussain *et al*., 2022; Balaji *et al*., 2022; Delcea *et al*., 2024; Essah *et al*., 2024; Frost *et al*., 2024; Ribeiro *et al*., 2024; Rosellini *et al*., 2024; Sanlier & Yasan, 2024; Uneno *et al*., 2024). Overall, the study highlights an integrative approach to male reproductive health that should be developed, which approaches combining semen analysis and functional assessment of sexual performance, especially in regions with environmental exposure to contamination. Addressing these impairments to prevent the allowances, detecting as early as possible, and reducing the exposure might play a role for the inhabitants in maintaining male reproductive potential and the overall effort to safeguard population health in environmentally undervalued surroundings (Adeleke, 2022; Razhaeva *et al*., 2022; Rojas *et al*., 2022; Sri *et al*., 2022; Al Abadie *et al*., 2023; Guzek *et al*., 2023; Lee *et al*., 2023; Ncube *et al*., 2023; Oran *et al*., 2023; Simonyan *et al*., 2023; Tsiganock *et al*., 2023).

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