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Histopathological Effects of Pyrethroid-Based Mosquito Coil Smoke on the Reproductive Organs of Rabbits

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Abstract

Pyrethroids are used as pesticides to control agricultural pests and ectoparasites in animals and humans. Compared with other insecticides, they are readily biodegradable and exhibit relatively low mammalian toxicity while remaining highly effective against insects. This study aimed to assess the toxic effects of mosquito-repellent coils (Mortein) on mammalian gonads using rabbits as the model organism. A total of 16 mature rabbits were divided into four groups (n=4/group). Four rabbits served as the control group, exposed only to normal room air, while 12 rabbits were assigned to experimental groups (R1, R2, R3) and exposed to mosquito-coil smoke for 3, 5, and 8 hours per day, respectively, for 30 days. On day 31, all rabbits were sacrificed and the gonads were extracted for histopathology. In males,

microscopic evaluation revealed degeneration of the spermatogenic layer, reduced spermatocytes, and proliferation of intertubular connective tissue. In females, irregular follicles, decreased follicular number, and cellular necrosis were observed. Given that Mortein coils are commonly used indoors in Pakistan, these findings indicate potential risks to human reproductive health. Therefore, alternative control methods should be considered, and exposure time minimized when coils are used.

Introduction

Mortein is the brand name of synthetic insecticides that act as insect repellents and is among the top ten brands in Pakistan (Abbas et al., 2015; Aslam et al., 2010). Mortein coils are typically spiral in shape and manufactured from a dry paste of pyrethrum powder. Mortein is a synthetic chemical similar to pyrethrins in pyrethrum extracts derived from *Chrysanthemum* (Tawatsin and Thavara, 2002). Pyrethroids, including cypermethrin, are designed to be effective for longer periods than natural pyrethrins (Khattab et al., 2016).

Active ingredients commonly found in insect-repellent coils include: 1) Pyrethrum—natural powdered material from *Chrysanthemum* plant species; 2) Pyrethrin—an extract of pyrethrum insecticidal chemicals; 3) Allethrin—the primary synthetic pyrethroid; 4) Esbiothrin—a derivative of allethrin; 5) D-butyl hydroxy toluene (BHT)—an additive to prevent pyrethroid oxidation during combustion; 6) Piperonylbutoxide (PBO)—a synergist that increases pyrethroid effectiveness; 7) N-octyl bicycloheptene dicarboximide (MGK 264)—an optional synergist; 8) D-trans allethrin (Ravi, 2014; Garba, 2007; John et al., 2015; Liu et al., 2003; Avicor et al., 2014). The most common active ingredients in coils are various pyrethroids, such as allethrin and d-allethrin.

Pyrethroid insecticides are categorized into two types: Type I causes abnormal sensitivity and fine tremors leading to exhaustion, while Type II causes ptyalism and coarse tremors progressing to neck and tail movement; both types can induce body-wide trembling and salivation (Lawrence and Casida, 1982; Shafer et al., 2005; Gammon et al., 1981; Verschoyle and Aldridge, 1980). Pyrethroids delay activation and inactivation of voltage-sensitive sodium channels (VSSCs), shifting membrane potentials and causing prolonged channel opening. Consequently, more sodium ions cross the neuronal membrane, leading to persistent depolarization. Type II pyrethroids markedly delay VSSC closure and depolarize membrane potential, often generating repetitive action potentials (Shafer et al., 2005).

Pakistan's insecticide market comprises approximately 1% fungicides, 11% herbicides, and 88% pesticides (Husain, 2002). Severe pyrethroid poisoning is rare in developed countries but more common in developing nations where usage is extensive (Bateman, 2000). The World Health Organization (WHO) recommends avoiding insect repellents of severe toxicity; in Pakistan, pyrethroids are widely utilized (Plestina, 1984; Aslam et al., 2010). Synthetic pyrethroids are among the most commonly used insecticides due to their broad efficacy, rapid biodegradation, relatively low mammalian toxicity, and target-specific action. Cypermethrin is widely applied in agriculture, forestry, public health, and animal health programs (Diabate et al., 2002; Khan et al., 2009; Saillenfait et al., 2015). Investigators have reported that coil smoke contains carbonyl compounds such as acetaldehyde and formaldehyde, which can produce strong irritant effects in the upper respiratory tract in humans (Chang et al, 1991). Prolonged exposure can induce persistent wheeze and asthma in children (Koo and Ho, 1994). Toxicological impacts of coil smoke include local degeneration of tracheal epithelium, epithelial metaplasia, and morphological disruption of alveolar macrophages (Liu, & Sun, 1988). Cypermethrin is toxic for mammals as well as insects (Barlow et al., 2001). Following high-dose consumption of cypermethrin, muscle tremors, ataxia, limb weakness, unconsciousness, and death from respiratory depression have been reported in animals; dermal contact can cause sensations of burning or numbness (Sandhu and Brar, 2000; Tonini et al., 1990). Globally, an estimated 45–50,000 tons of mosquito coils are used annually by roughly two billion people (Zhang et al., 2010). A single coil may emit fine particulates equivalent to 75–135 cigarettes, depending on the coil material (Liu et al., 2003).

MATERIALS AND METHODS

A total of 16 mature rabbits free of apparent disease were purchased from the local market. Animals were housed individually in wire cages in a ventilated animal house at 29–32°C with a 10–12-hour photoperiod. Fresh green fodder and drinking water were supplied. Commercial Mortein mosquito-repellent coils (12 cm diameter; 15.0 g weight) were purchased from a local market.

Rabbits (1.5–2.5 kg) were allocated to four equal groups (n=4/group): one control group (C) and three experimental groups (R1, R2, R3). The control group was exposed to ambient fresh air. Experimental groups were exposed to coil smoke for 30 consecutive days as follows: R1, 3 hours/day; R2, 5 hours/day; R3, 8 hours/day. Coils were placed approximately 6 inches from the cages with a closed cover on one side to facilitate smoke circulation (Figure 1).

At the end of the exposure period, control and experimental rabbits were humanely euthanized with chloroform. Reproductive organs were exposed via midline incision, carefully removed, and subjected to physiological and histopathological assessments. Outcomes included gonadal weight (measured on an electronic balance) and light-microscopic histopathology (hematoxylin and eosin staining).

Figure 1: Exposure of Mortein Mosquito coil smoke to Rabbits.

RESULTS

Physio-clinical alteration:

During the experimental period, mortality was recorded only in the 8-hour exposure group (R3). No abnormal neurological or behavioral signs were observed in the control group (A). In both male and female rabbits, hyper-irritability, reduced attraction to fodder and water, lethargy, ptyalism, puffing, increased eyeball movement, pupil dilation, and lacrimation were observed in the 8-hour exposure group. Across the 5- and 8-hour exposure groups, additional symptoms included sleepiness, motion sickness, mild eye irritation, persistent coughing, slight salivation, and nose scratching. All experimental animals exhibited generalized weakness, lethargy, and decreased appetite. In all experimental groups, the tip of the nose of rabbits turned yellow after one week of coil exposure. In R3 (8 hours/day), the discoloration was dark yellow compared with R2 (5 hours/day) and R1 (3 hours/day), which were moderate and light yellow, respectively (A, B, C, D in Figure 2). Localized nasal irritation was evident.

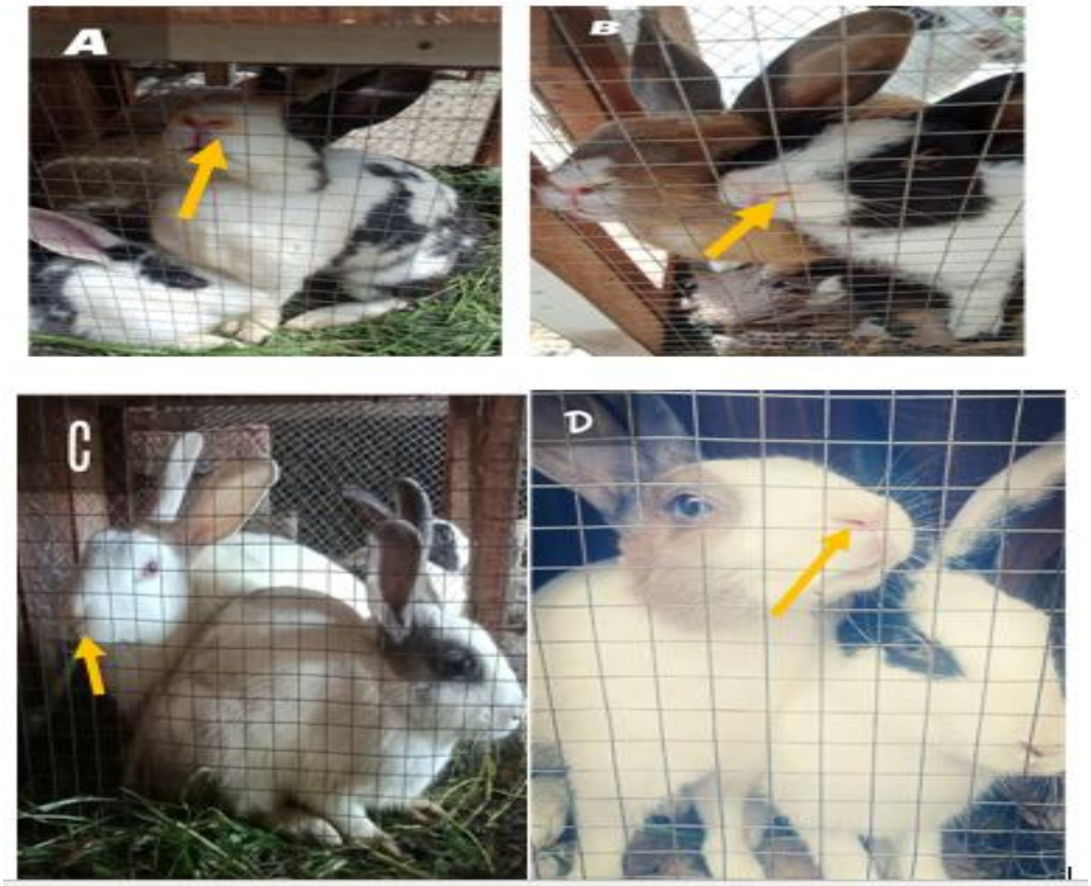

Figure 2: Nose tip discoloration in rabbits—R3 (A), R2 (B), R1 (C), and Control (D).

Body Weight:

Body weight of each animal was recorded weekly throughout the experimental period. All experimental groups showed a progressive reduction in body weight compared with the control group (Figure 3-4).

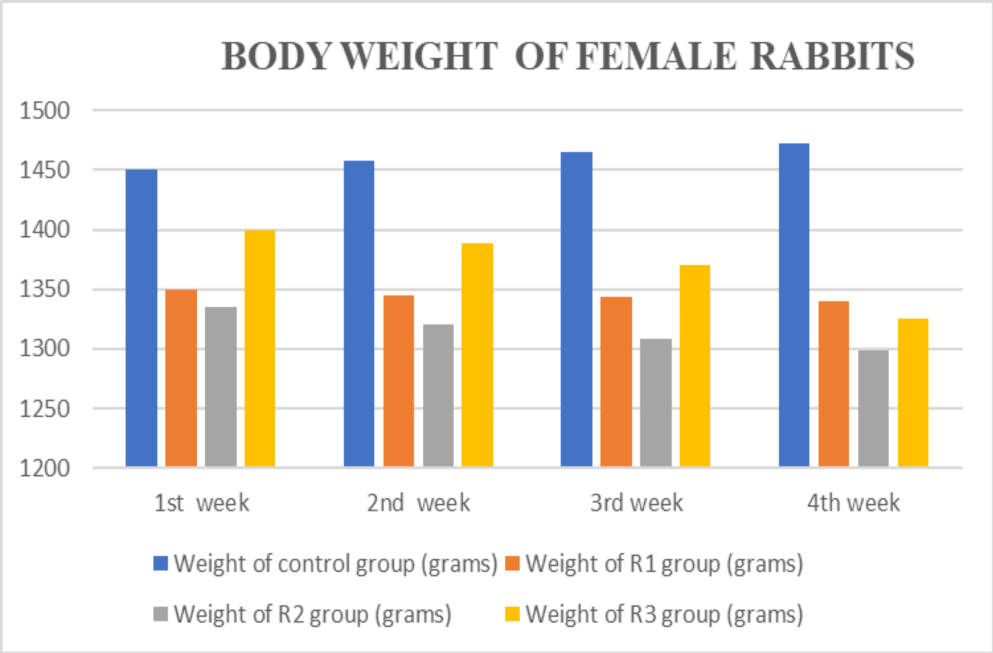

Figure 3: Body weight of female rabbits (weekly measurements).

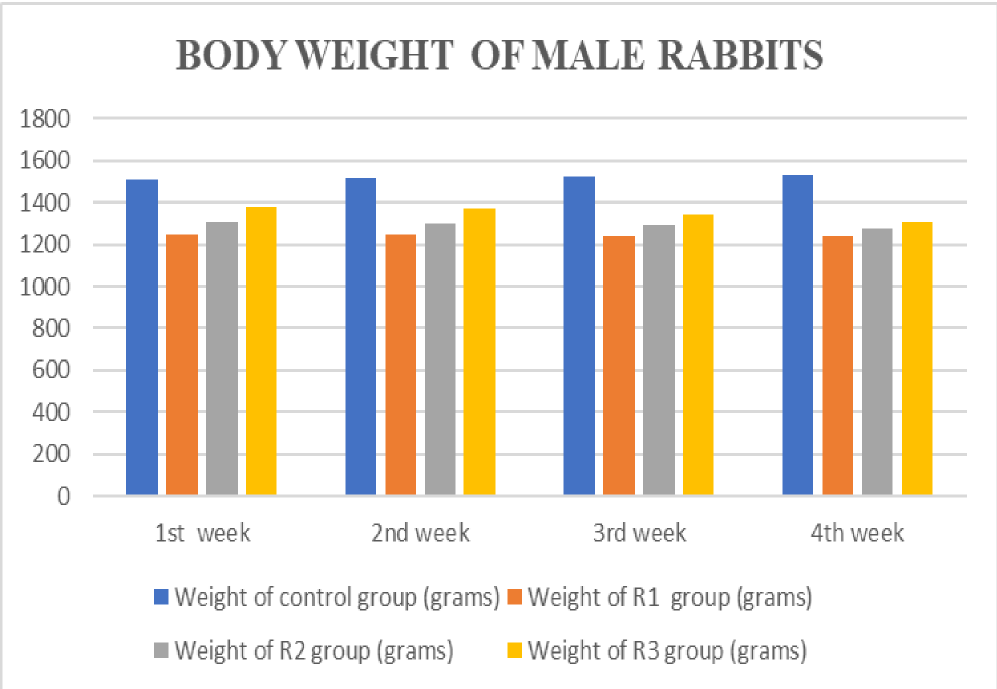

Figure 4: Body weight of male rabbits (weekly measurements).

Weight of Gonads:

Following extraction, gonadal weights were measured using an electronic balance. Gonadal weight increased in experimental animals relative to controls over the exposure period (Figure 5-6).

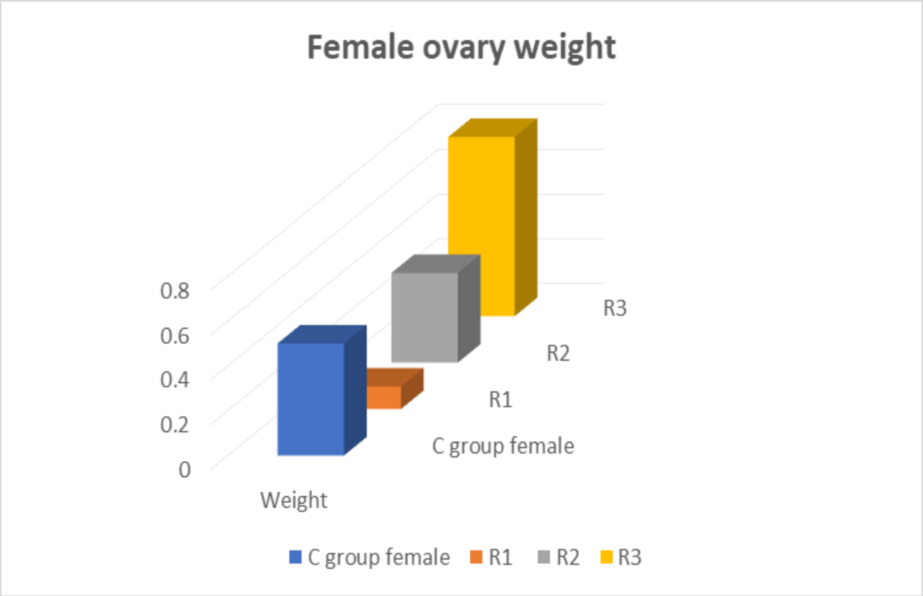

Figure 5: Weight of female gonads of rabbits.

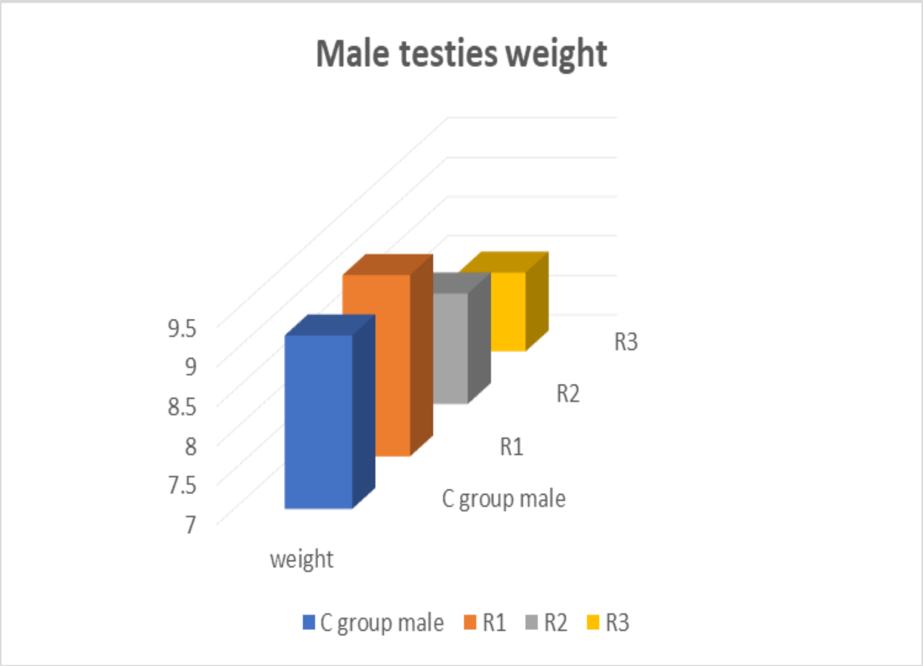

Figure 6: Weight of male gonads of rabbits.

Histopathology of Gonads:

Result of pyrethroid smoke exposure in male testis:

Control males showed organized spermatogenic architecture, well-shaped rounded seminiferous tubules, thin intertubular connective tissue, and abundant mature spermatids within tubules. The seminiferous epithelium consisted of Sertoli cells and layers of spermatogenic cells enclosed by a basal membrane (Figure 7).

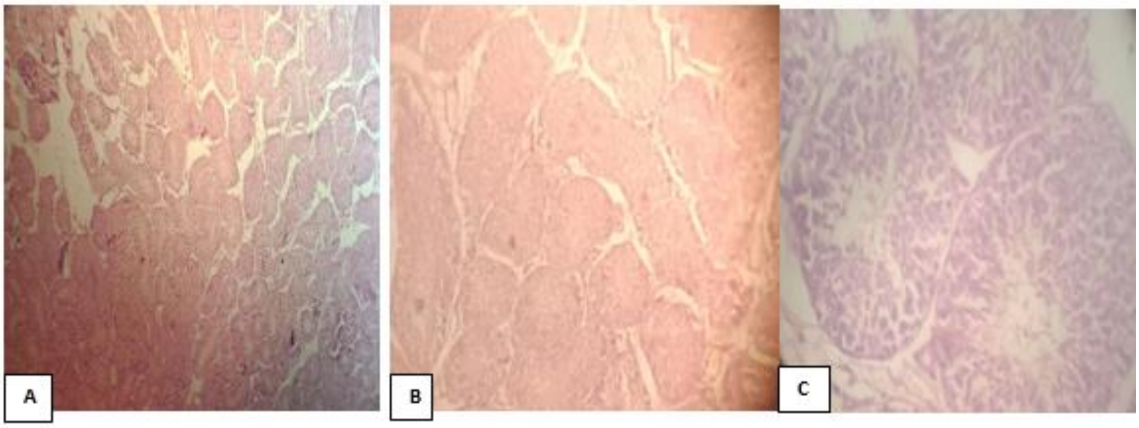

Figure 7: Control testis—organized spermatogenic layers, rounded seminiferous tubules, thin intertubular connective tissue, and abundant mature spermatids. H&E; 4× (A), 10× (B), 40× (C).

In R1 (3 hours/day), degenerated spermatogenic layers with a decreased number of cell layers were noted in some tubules (Figure 8).

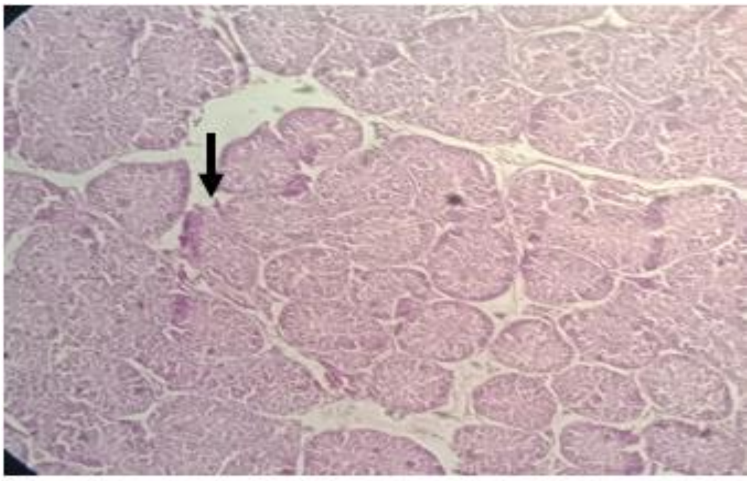

Figure 8: Three-hour/day coil-smoke exposure—degenerated spermatogenic layers (arrow) with reduced cell layers in some tubules. H&E; 10x.

In R2 (5 hours/day), tubules contained a small population of spermatogenic cells—spermatocytes, spermatids, and spermatozoa. Proliferation of connective tissue among seminiferous tubules was evident, leading to reduced tubule diameter and focal apoptosis (Figure 9).

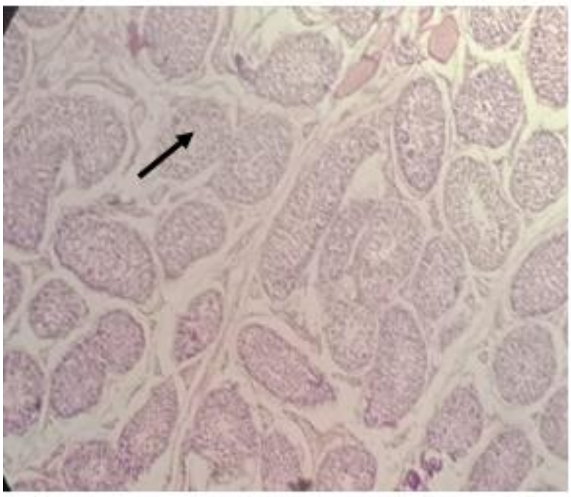

Figure 9: Five-hour/day coil-smoke exposure—reduced spermatogenic cell populations (arrow), connective tissue proliferation, decreased tubule diameter, and focal apoptosis. H&E.

In R3 (8 hours/day), the tubular epithelial structure was disrupted with defective germinal layers. Progressive alterations, including loss of spermatogonia and Sertoli cells, were exposure dependent, with fewer cells remaining overall (Figure 10).

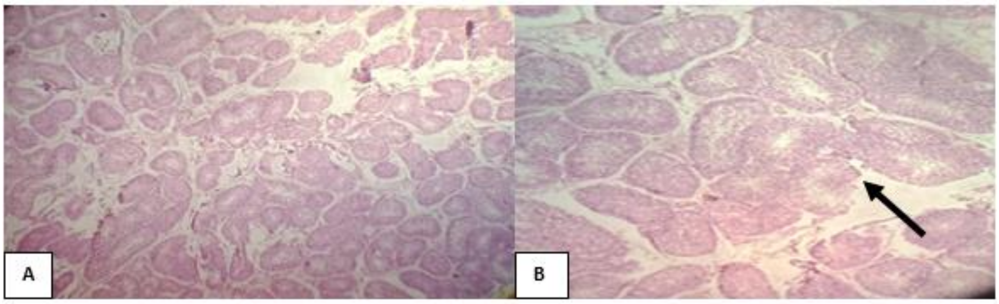

Figure 10: Eight-hour/day coil-smoke exposure—disrupted tubular epithelium (arrow) and defective germinal layers; exposure-dependent degenerative changes with loss of spermatogonia and Sertoli cells. H&E; 10x and 40x.

Result of pyrethroid smoke exposure in female gonads:

Control females exhibited normal ovarian architecture, including developing follicles (primordial, pre-antral, and antral), Graafian follicles, corpora lutea, and atretic follicles in the cortex beneath surface epithelium (Figure 11).

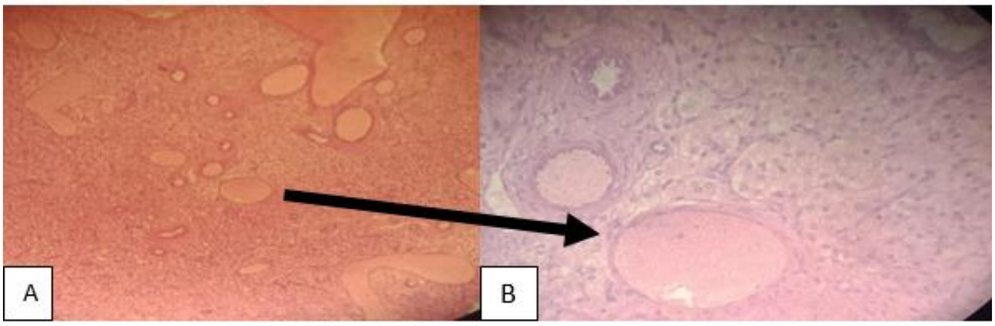

Figure 11: Control ovary—normal cortical structures with developing follicles and corpora lutea. H&E; 10x (A), 40× (B).

In R1 (3 hours/day), follicles showed irregular follicular and oocyte borders (Figure 12).

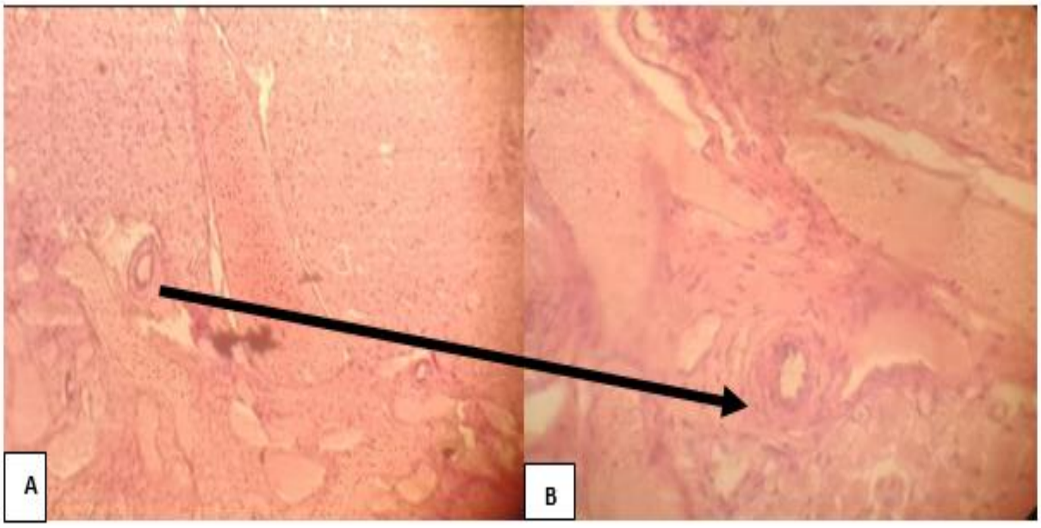

Figure 12: Three-hour/day coil-smoke exposure—irregular follicle and oocyte borders. H&E; 10x (A), 40x (B).

In R2 (5 hours/day), the number of follicles decreased relative to controls, and existing follicles displayed deformed structure (Figure 13).

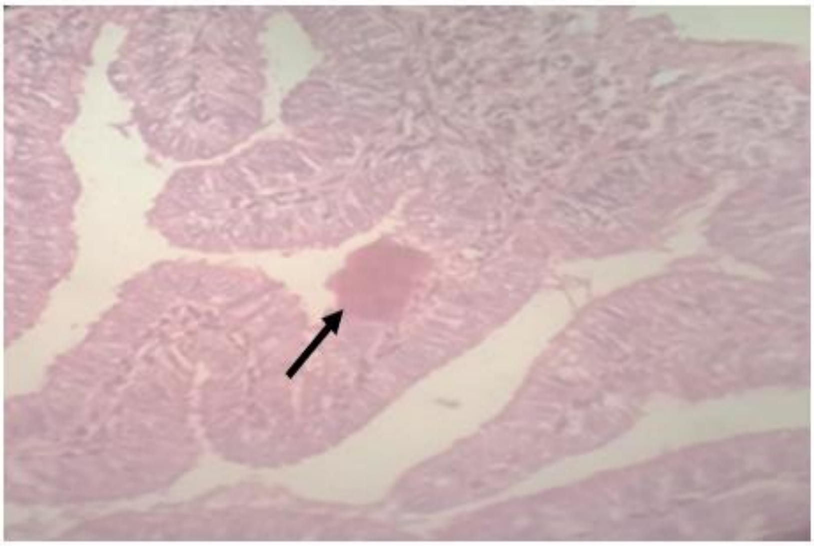

Figure 13: Five-hour/day coil-smoke exposure—reduced follicle number, deformed follicular structure, and focal necrosis. H&E; 40x.

In R3 (8 hours/day), there was marked reduction and complete loss of follicular cells and oocytes, with diminished albuminous fluid in Graafian follicles; necrosis was evident across treated groups, indicating potential fertility toxicity (Figure 14).

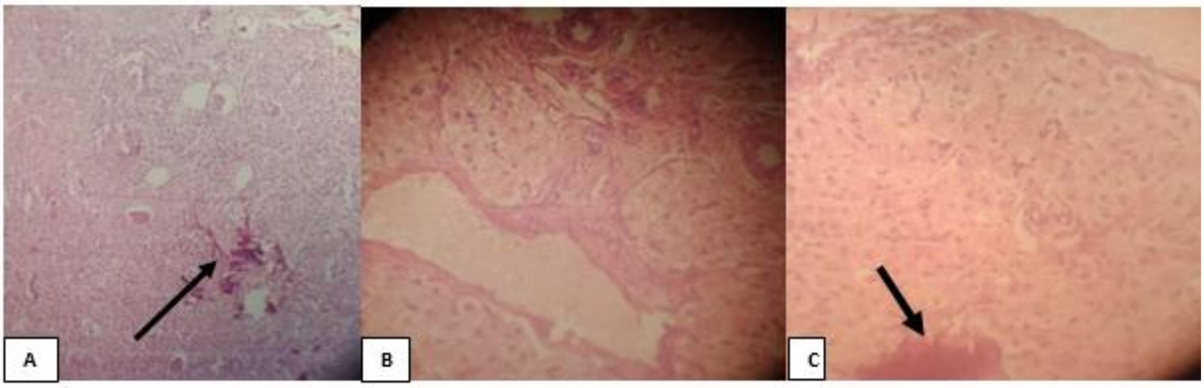

Figure 14: Eight-hour/day coil-smoke exposure—necrosis within follicles and loss of follicular cells/oocytes. H&E; 4x (A), 10x (B), 40x (C).

DISCUSSION

Mortein is the brand name of synthetic insecticide that acts as insect repellent and is among the top 10 brands of Pakistan (Abbas et al., 2015; Aslam et al., 2010). Mortein contains cypermethrin, a pyrethroid insecticide. It is a synthetic chemical similar to pyrethrins derived from *Chrysanthemum* (Tawatsin and Thavara, 2002). Pyrethroids, including cypermethrin, are designed to be effective longer than pyrethrins (Khattab et al., 2016).

Integrating pesticide exposure with signs and symptoms of acute pesticide-related illness is intricate, and health workers must prioritize clinical, environmental, and occupational exposure histories (Calvert et al., 2003). In the current study, symptoms observed in male rabbits included dullness, pupil enlargement, increased eyeball movement, skin irritation, lacrimation, hypothermia, coarse tremors, gasping, and ptyalism. Similar manifestations have been reported in sheep—dullness, irritation, and ptyalism (Neuschl et al., 1995), goats (Khan et al., 2009), and rats (Manna et al., 2004; Taiwo et al., 2008).

Pyrethroids cause a rapid increase in sodium influx and depolarize neuronal membranes by delaying sodium-channel inactivation; this can produce the neurological signs mentioned above. At the peripheral nervous system, pyrethroids antagonize chloride channels, contributing to ptyalism, while central effects produce motor signs of intoxication (Soderland et al., 2002). In the current study, pupil enlargement and ocular discharge were consistent with observations in buffalo calves (Jagvinder et al., 2001) and rabbits (Lakkawar et al., 2004). Respiratory distress and related symptoms have been described in goats treated with pyrethroids (Tamang et al., 1991), in rats (Hext, 1987; Iyaniwura and Okonkwo, 2004), and in humans (Lessenger, 1992; Taguchi et al., 2006).

The irritation-related respiration, coarse tremors, and dullness observed here agree with previous reports (Neuschl et al., 1995; Taiwo et al., 2008; Manna et al., 2004; Khan et al., 2009). In this study, pyrethroid-treated females showed more obvious complications of shorter duration compared with males. In a clinical trial comparing monotherapy and combination nucleoside-analog therapy designed to examine toxicity differences between sexes, baseline CD4 counts were significantly higher in women than in men (Currier et al., 2000).

A substantial reduction in body weight accompanied by variable changes in daily feed intake was recorded across experimental groups compared with controls. These findings are consistent with previous reports in rabbits (Lakkawar et al., 2004; Shah et al., 2007; Ullah et al., 2006), chickens (Aslam et al., 2010), and rats (Ratnasooriya, 2003), though they differ from those reported by Neskovic (1998) and Sayim et al. (2005) in chickens and rats, respectively.

Histologically, in male rabbits, degenerated spermatogenic layers, spermatogonial pyknosis, decreased spermatozoa, and proliferation of connective tissue between seminiferous tubules observed in this study are consistent with findings in mice (Zhang et al., 2010), rats (Alhazza and Bashandy, 1998; Elbetieha et al., 2001; Sakr and Azab, 2001), and goats (Ahmad et al., 2009). These abnormalities may reflect DNA damage, as documented among workers exposed to pyrethroids (Bian et al., 2004). In females, abnormal follicular structure, cellular necrosis, and reduced follicular cells observed here agree with reports in rabbits (Ullah et al., 2006) and rats (He et al., 2006).

CONCLUSION

Chronic exposure to pyrethroid-containing mosquito coils can lead to behavioral, reproductive, and pathological abnormalities in animals. In rabbits, pyrethroid toxicity produced clinical and behavioral changes such as discomfort, increased urination, anxiety, muscle tremors, incoordination, and reduced feed intake. The observed testicular and ovarian histopathology indicates impaired spermatogenesis, follicular degeneration, and compromised fertility, suggesting reduced reproductive performance in both sexes. Pyrethroid exposure during early life also raises concerns for teratogenic and fetotoxic risks. Given the widespread indoor use of Mortein coils in Pakistan, overuse should be avoided. If coils are used, exposure duration should be minimized and safer alternatives should be promoted.

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