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Research article

Some Toxic Effects of Sio2 NPs on Thyroid Gland Function with Histological Changes and Ovary Function in Female Rats

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ABSTRACT

The study investigated the effects of Silicon Dioxide Nanoparticles (SiO2 NPs) on female rats' thyroid glands and ovaries. Three groups were randomly selected, and two treatment groups were given different SiO2 NPs (25 mg/kg and 100 mg/kg of body weight). The animals were divided into three experimental groups. The thyroid (T3, T4, and TSH), and ovarian (E2 and progesterone) function hormones were measured. The histological study was studied. It was found that significant decrease in T3 levels in the rats group treated with SiO2 NPs doses over 10 days as compared with the control group. The significant decrease in T4 levels was also found in the treated rats groups (10, 20, and 30 days) as compared with the control group. However, a significant elevation in TSH was seen in treated groups as compared with the control group. The current study showed that exposure to SiO2 NPs caused thyroid tissue alteration, with certain follicles filled with colloidal scalloping activity. When exposed to 100 mg/kg of SiO2 NPs for 10 days, more scalloping formation was observed. When treated with 25 mg/kg of SiO2 NPs for 20 days, few follicles filled with colloidal were observed. When treated with 100 mg/kg of SiO2 NPs for 20 days, empty follicles with necrotic cells were observed. In conclusion, SiO2NPs produced structural, functional, and ovarian effects at different concentrations. In the thyroid gland, they decreased T3 and T4 hormone levels and increased TSH levels. In the ovary, they caused structural, functional, and decreased E2 and progesterone levels.

Keywords: Estradiol (E2), female rats, T3,T4, TSH, Histological change, ovary, progesterone, Sio2NPs, thyroid gland

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1. INTRODUCTION

Nanotechnology refers to the creation, production, and use of, macromolecular, molecular, and materials at the atomic levels to generate new nanoparticles [1]. These particles may be identified by their tiny size, which falls between 1 - 100 nm [2]. Nanoparticles are classified based on their physiological and chemical characteristics, one of which is silicon dioxide nanoparticles [3]. In the medicinal industry, SiO2 NPs are widely used as drug delivery vehicles, biomarkers, and cancer therapies. In the nonmedical field, they are added as chemicals to polish chemicals, varnishes, cosmetics, and food items [4]. Nanoparticles can enter the body in a variety of methods, including intentional injection, inhalation, absorption via the skin or digestive system, and implantation to provide medication. Then these particles interact with biological systems, the exposed living things may experience both favorable and unfavorable outcomes. This is because NPs may be ingested by cells, which then interact with cellular organelles [5]. However, other research indicates that food NPs may cause systemic or

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local toxicity, which raises questions regarding potential health hazards [6]. Mice and rats are given oral AgNP doses of up to 2.5 mg/kg body weight every day, they may experience weight loss, intestinal microvilli epithelial cell destruction, severe colon inflammation, oxidative liver toxicity, inflammation, or disruption of lipid metabolism [7]. Long-term research in rats or mice showed conflicting outcomes regarding SiO2 NPs. The toxicity was documented with long-term oral SiO2 NP treatment [8]. Since the endocrine system is very susceptible to poisons from the environment, 10% of people are thought to have thyroid gland issuesGiven that, certain nanoparticles affected thyroid gland function and histology in female rats in a time and dose-dependent way; this may be regarded as a serious public health issue [9]. Given the mounting evidence that NP may enter the ovary and affect normal activities. Data describing toxicity to ovarian activities, such as follicular growth, oocyte quality, fertility, and the synthesis of sex steroid hormones, as well as data on NP accumulation in ovarian tissue. Due to their relevance to toxicology, additional research has also described the primary physicochemical features of NP toxicity and the significance of considering these features when evaluating NP physicochemical properties as variables determining NP ovarian toxicity [10]. The current study set out to investigate how intraperitoneally delivered Sio2NPs affected the thyroid and ovarian glands of female rats.

2. MATERIAL AND METHODS

2.1. Experiment Design

In this work, an injectable solution of varying concentrations was prepared by dissolving the powdered sio2 nanoparticles in distilled water and vortexed for ten minutes to form the SIO2NP suspension. Two concentrations of SiO2NP solution were created (25 mg/kg for a low dosage and 100 mg/kg for a high dosage). Fifty-four mature female Sprague-Dawley rats, weighing 225-250 g and aged between 8 and 10 weeks. They were taken from AL Nahrain University's Biotechnology Research Centre in Baghdad, Iraq. Before the study began, the animals were held at the Biotechnology Research Center lab at AL Nahrain University for fifteen days to adapt. The conditions comprised a precisely 12-hour light/dark cycle and a regulated temperature of 25 °C. For food and drink, the animals were given pellets and tap water.

The experimental animals were divided into three groups at random: control and treatment. Following the intraperitoneal approach, each group was divided into three subgroups based on the post-injection period (10, 20, and 30 days of daily dosages per week, excluding public holidays). Each subgroup, consisting of six rats, is depicted below.

- Animals in Groups 1, 2, and 3 served as controls (injected intraperitoneal with sterile distilled water).
- Animals in groups 4, 5, and 6 were injected intraperitoneal with a low dosage of SiO2 NPs (25 mg/Kg).
- Animals in groups 7, 8, and 9 were injected intraperitoneal with a high dosage of SiO2 NPs (100 mg/Kg body weight).

The blood samples were collected and the sera were prepared for the hormonal and biochemical tests by centrifuging it for 15 min at 3000 rpm. The sera were divided into multiple equal amounts and kept in Eppendorf tubes at -20°C. Measurements of thyroid and ovarian hormones (T3, T4, TSH, E2, and progesterone) in blood samples were made using the Cobase 6000 (c501) analyzer [11]. The histopathological examination was carried out according to the previous study [12].

2.2. Statistical analysis

Statistical Analysis System, SAS, (2012) was utilized to ascertain how different factors affected each of the study's parameters. To further compare the means, the Analysis of Variation (ANOVA) test for the least significant difference (LSD) was employed.

3. RESULT

The research included determining the thyroid gland hormone levels for T3, T4, and TSH to examine how the gland functions. For each animal exposed to SiO2 NPs, the T3 hormone was assessed. When comparing the animals exposed to SiO2 NPs at low and high doses (25 and 100 mg/kg) over 10 days, the results indicate a substantial reduction ($p<0.05$) (1.22 ±0.011) and (1.16 ±0.008), respectively, in comparison to the control group (1.40 ±0.003). Furthermore, the results indicate a substantial ($p<0.05$) drop in T3 levels (1.18 ±0.008) and (1.12 ±0.007) for all animals treated with these doses during 20 days when compared to the control group (1.43 ± 0.21). In contrast to the control group (0.810 ±0.02), the results for 30 days showed a substantial ($p<0.05$) rise in the T3 level in the serum of the animals treated with both dosages of SiO2 NPs (0.920 ±0.04) and (0.810 ±0.02), respectively, as that shown in Figure (1).

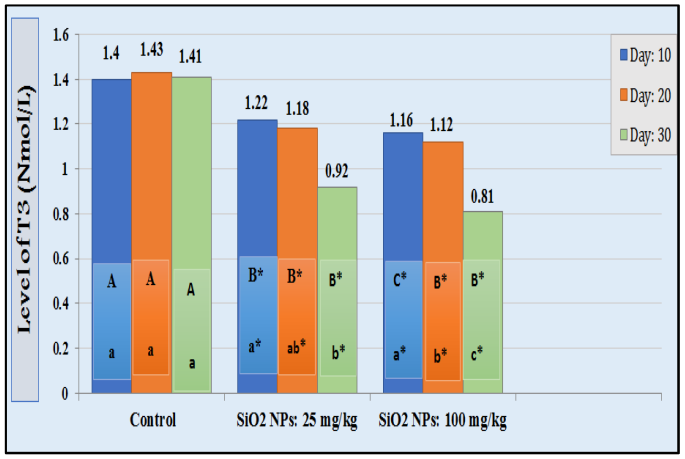

Fig. 1 Rats' T3 hormone was affected by SiO2 NPs at two distinct doses (25 and 100 mg/kg) and at different exposure times. *, Mean a statistically significant difference (p≤0.05). (A, B, C), Show the significant difference between the groups when time is regarded as a variable factor and concentration is kept constant.

T4 hormone level was measured over 10 days. It was shown that the animals exposed to SiO2 NPs at both dosages (25 and 100 mg/kg) (35.15 ±0.74) and (31.14 ±0.82) respectively had significantly lower levels ($p<0.05$) as compared with the control group (45.86 ±1.49). Furthermore, all animals given these doses for 20 days showed a substantial ($p<0.05$) drop in T4 hormone levels (23.32 ±0.72) and (21.63 ±0.60), respectively, as compared to the control group (47.34 ±0.73). Lastly, compared to the control group (48.3±2.01), all animals treated with SiO2 NPs for 30 days had significantly lower levels of T4 hormone ($p<0.05$) (16.31 ±0.37) and (13.83 ±0.56), respectively (Figure 2). Lastly, about the TSH hormone results, Figure 3 showed a significant increase ($p<0.05$) in the animals exposed to SiO2 NPs at two doses (25 and 100 mg/kg) over 10 days (2.145±0.001) and (2.182±0.002), respectively, in comparison to the control group (0.197±0.001). Furthermore, compared to

the control group (0188 ±0.001), there was a significant increase (*p<0.05*) in the TSH levels of treatment animals receiving these

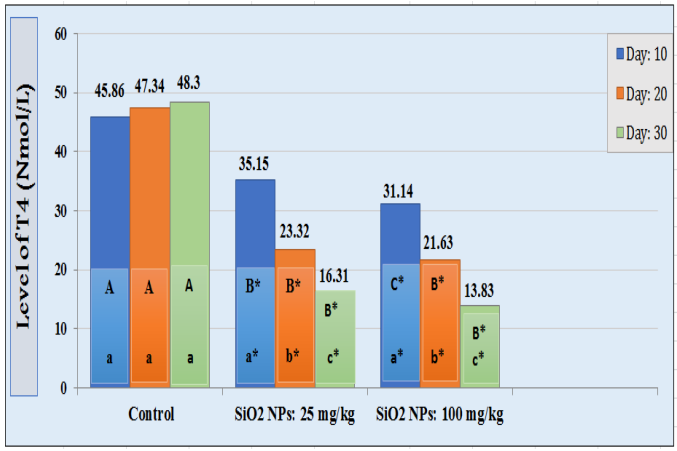

Fig. 2. Rats' T4 hormone was affected by SiO2 NPs at two distinct doses (25 and 100 mg/kg) and at different exposure times. *, Mean a statistically significant difference (p≤0.05). (A, B, C), Show the significant difference between the groups when time is regarded as a variable factor and concentration is kept constant.

two dosages (2.25 ±0.17) and (2.42 ±0.30), respectively, during 20 days. Finally, when compared to the control group (0.195 ±0.02), the results showed a substantial rise (*p<0.05*) in the level of TSH hormone in all animals treated for 30 days with both dosages (3.152 ±0.17) and (3.621 ±0.27) respectively.

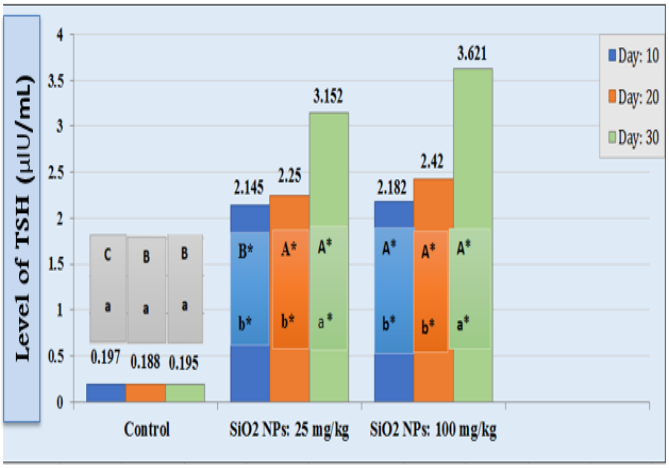

Fig. 3. Rats' TSH hormone was affected by SiO2 NPs at two distinct doses (25 and 100 mg/kg) and exposure times. *, Mean a statistically significant difference (p≤0.05). (A, B, C), Show the significant difference between the groups when time is regarded as a variable factor and concentration is kept constant.

The present study showed the effect of exposure to different concentrations of SiO_2 NPs for different intervals of time (10, 20, and 30 days), the results were compared with the sections of the thyroid gland that were collected from control groups of rats (Fig. 4). The section of thyroid gland tissue after exposure to 25mg (low dose) SiO_2 NPs for 10 days showed certain follicles filled with colloidal scalloping activity and other follicles were empty from colloidal material as shown in Fig 5. In the section of thyroid gland tissue after exposure to 100 mg (high dose) SiO_2 NPs for 10 days showed more scalloping formation and the cells still there was empty follicles, as shown in Fig 6.

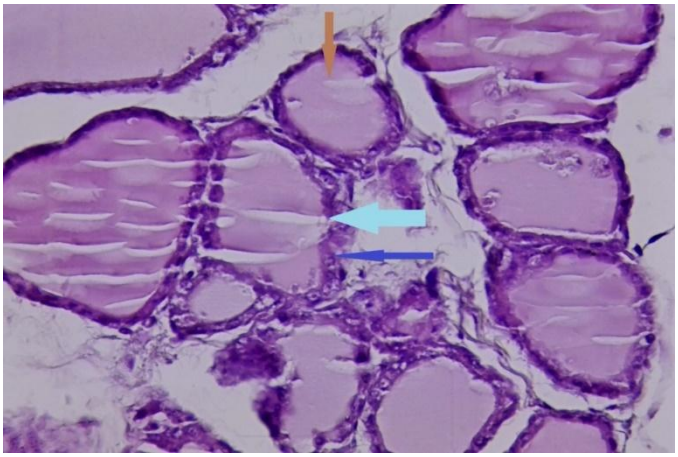

Fig. 4. Section of the thyroid gland of the control group showing the normal structure of the thyroid follicles(Light arrows) which contain colloid materials(Brown Arrows) that are lined by cuboidal epithelium cells(Dark blue arrows), (H&E) 40x.

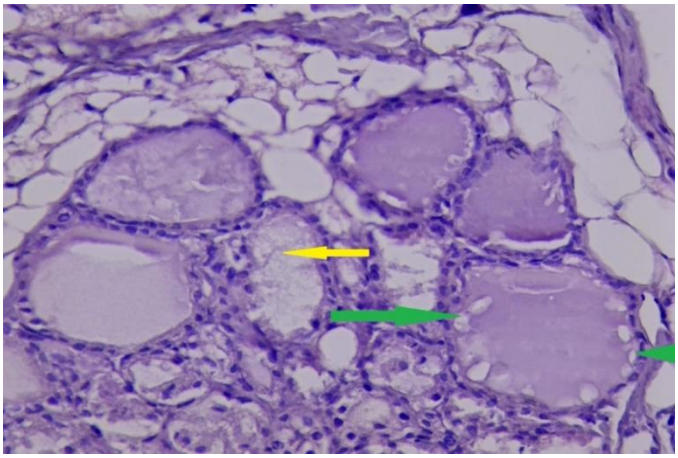

Fig. 5. Section of thyroid gland of rat group treated with 25 mg/kg of SiO2 NPs for 10 days, showing certain follicles filled with colloidal with scalloping activity(Green arrows) and other follicles were empty(yellow arrows) from colloidal material,

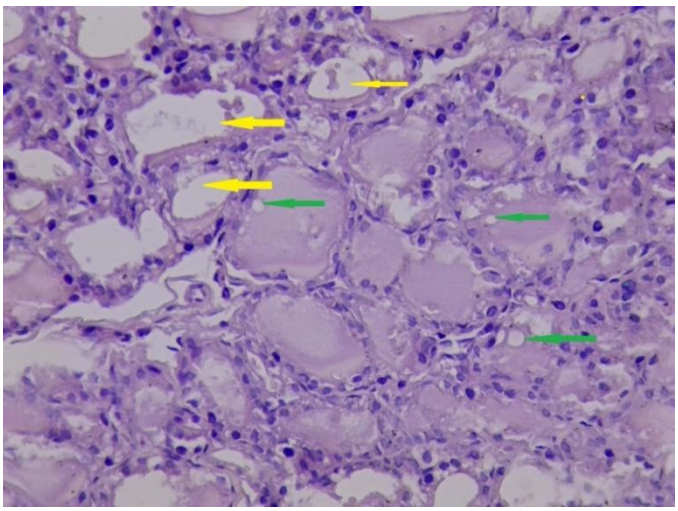

Fig. 6. Section of thyroid gland of rat group treated with 100 mg/kg of SiO2 NPs for 10 days, showing more scalloping formation(Green arrows) and the cell still there was empty follicles(Yellow arrows), (H&E) 40x.

As well cross-section of thyroid gland tissue after exposure to low dose (25mg/kg) SiO_2 NPs for 20 days, section showing few follicles filled with colloidal while the maturity of follicles well empty and there were necrotic cells (inside the lumen of follicles) Fig 7.

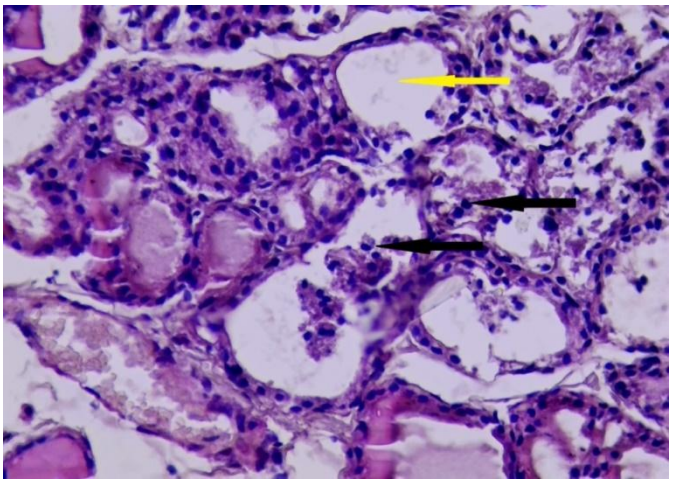

Fig. 7. Section of thyroid gland of rat group treated with 25 mg/kg of SiO2 NPs for 20 days, showing few follicles filled with colloidal while the maturity of follicles well empty Yellow arrows)and there was necrotic cell (inside the lumen of follicles, black arrows), (H&E) 40x

However, in contrast, groups of rats given a high dosage (100 mg/kg) of SiO2 NPs for 20 days displayed empty sections representing the maturity of follicles, as well as an increase in the size of thyroid follicles cells Fig 8. On the other hand, the thyroid gland tissue section that was studied in rats administered a low dose of 25 mg/kg for 30 days showed empty follicles, dead cells, increased cell division, and the formation of new follicles that were unable to function normally Fig 9. In addition, the thyroids sections exhibited an increase in depleted and damaged follicles, along with an elevated presence of colloidal follicles and flattened epithelial follicular cells with necrotic cell appearance, following 30-day exposure to a high dosage (100 mg/kg) Fig 10.

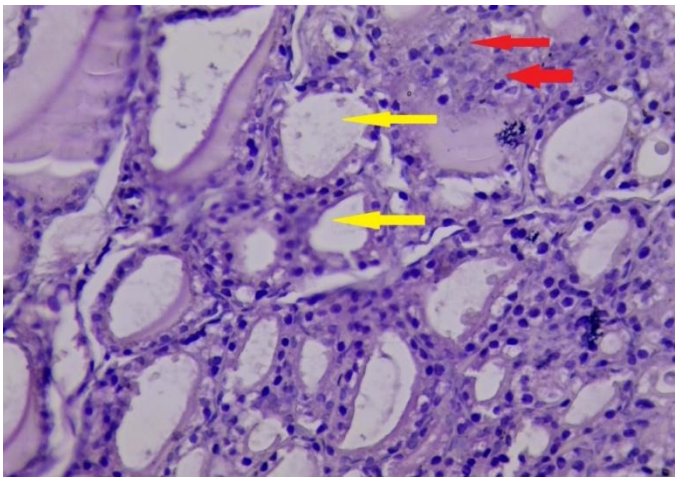

Fig. 8. Section of thyroid gland of rat group treated with 100 mg/kg of SiO2 NPs for 20 days, showing the maturity of follicles was empty(yellow arrows) and hyperplasia of thyroid follicles cell(Red arrows), (H&E) 40x.

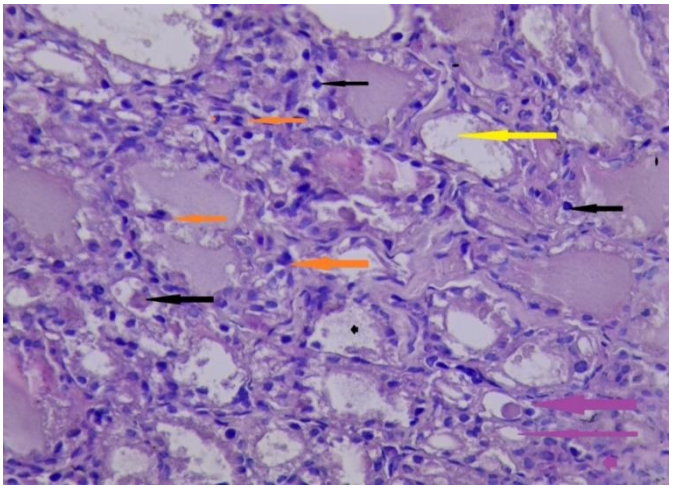

Fig. 9. Section of thyroid gland of rat group treated with 25 mg/kg of SiO2 NPs for 30 days, showing empty follicles(yellow arrows) with necrotic cell(Black arrows), mitotic activity(Orange arrows) and formation new nonfunctional follicles, (H&E) 40x

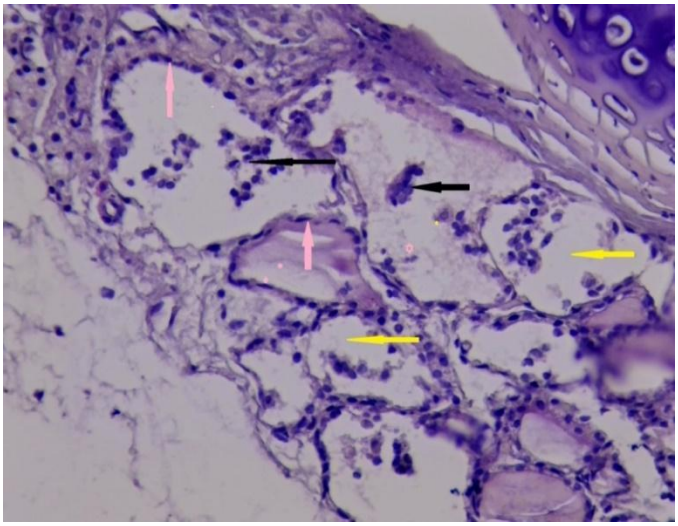

Fig. 10. Section of the thyroid gland of the rat group treated with 100 mg/kg of SiO2 NPs for 30 days, showing more empty destroy follicles(Yellow arrows) and more colloidal follicles and flattened epithelial follicular cells (Pink arrows) with necrotic cells (Black arrows), (H&E) 40x.

In this work, it was expected that oxidative injury produced by chronic exposure to Sio2NPs could result in hormonal and structural alterations in the thyroid gland. Microscopic examination of thyroid tissue revealed a significant histological change in the thyroid tissue after exposure to a low and high dose (25 and 100mg/kg) of Sio2Nps for 10, 20, and 30 days, manifested by follicular colloidal material depletion and necrotic injury of the follicular epithelial cells, which was found to be increased with longer duration.

In addition, the study investigated the ovary's activity by assessing the levels of the chemicals E2 and progesterone. Statistical analysis revealed a significant decrease in E2 hormone levels ($p<0.05$) for animals exposed to SiO2 NPs at both doses (25 and 100 mg/kg) (46.21 ±0.33 and 44.32 ±0.73, respectively) over 10 days compared to the control group (51.23 ±0.48). Furthermore, there was a notable reduction with statistical significance ($p<0.05$) in the E2 levels among all the

animals that were exposed to these particular doses of 35.36 ±0.91 and 31.81 ±0.63 respectively, over 20 days. This decrease was observed in comparison to the control group's E2 level (51.46 ±0.87). Ultimately, the findings indicated a noteworthy reduction ($p<0.05$) in the E2 hormone levels of animals that received treatment for 30 days with either dosage of SiO2 NPs. Specifically, the E2 hormone levels were measured to be 22.25 ±0.46 and 18.65 ±0.19 for the two doses, respectively, compared to the control group 51.67 ±0.53 (Fig. 11).

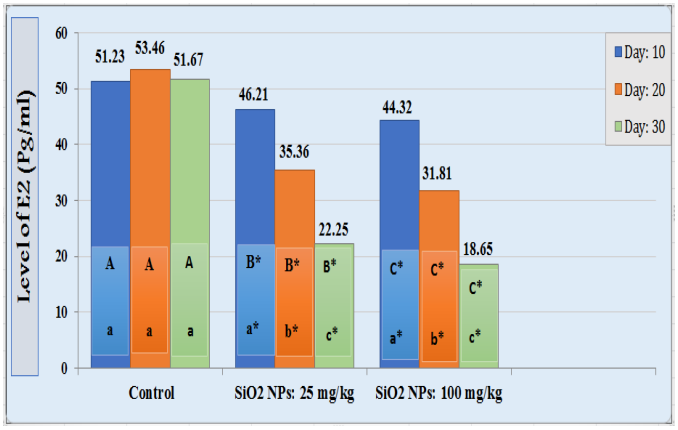

Fig. 11. Effects of different dosages (25 and 100 mg/kg) of SiO2 NPs on the levels of the hormone estrogen in rats over various time intervals were examined.

While examining the statistical analysis data depicted in Fig 12, it was observed that there was a noteworthy reduction in the progesterone hormone levels ($p< 0.05$) among animals exposed to SiO2 NPs at both doses of 25 and 100 mg/kg for 10 days. The progesterone levels for the exposed groups were recorded as 10.52 ±0.47 and 10.13 ±0.40 respectively, in comparison with the control group (12.68 ±0.35). Also, there was a significant decrease ($P < 0.05$) in the level of progesterone hormone of animals that exposed to both doses were 8.31 ±0.67 and 8.15 ±0.61 respectively, during 20 days when compared with the control group (12.42 ±0.59). Finally, there was a significant decrease ($P< 0.05$) in progesterone hormone of animals that were treated for 30 days at low and high doses of SiO_2 NPs were 7.24 ±0.21 and 6.11 ±0.21 respectively, when compared with the control group (12.15 ±0.24).

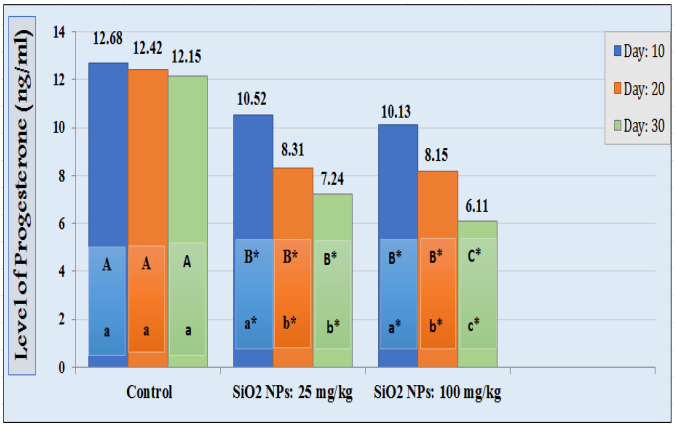

Fig. 12. The effects of different SiO2 NP concentrations (25 and 100 mg/kg) on rats' progesterone levels over various exposure times.

4. DISCUSSION

The current study's findings showed a consistent and significant decrease in thyroid hormone levels (T3 and T4), followed by a progressive increase in TSH levels. The pituitary gland secretes TSH, and the hypothalamus secretes TRH, which controls thyroid hormone production and release. The hypothalamic-pituitary-thyroid axis is commonly used to describe how thyroid hormone levels in the blood are regulated [13]. These findings were consistent with the results of a previous study reported by a prior study [14] When zebrafish larvae were subjected to a combination of Tio2 (0.1 mg/kg) nanoparticles and pentachlorophenol, their T4 hormone levels decreased significantly compared to the control group. In a previous study, it was proven that the levels of T3 and T4 hormones declined dramatically, while the levels of TSH hormone increased in the bloodstream of rats after they were injected intraperitoneally with a dosage of either 30 or 60 mg/kg for a duration of (7, 14, and 28 days) [15]. Furthermore, subsequent research has demonstrated that the injection of Silver nanoparticles AgNPs at different concentrations (12, 5, 25, and 50mg/kg) over 4 weeks resulted in a significant decrease in the levels of T3, and T4 in the rats' serum [16]. However, this study contradicted a previous study that showed after administering an intraperitoneal injection of a 0.5 ml solution of Fe2Nio4 nanoparticles to rats for 2, 7, and 14 days, the TSH hormone level decreased, there was no significant change in the T3 level, but there was a significant increase in the T4 level in their serum. An experiment conducted on rats found that a combination of Fe2O3NPs (administered orally) at a dosage of 5mg/kg and Silver nanoparticles AgNPs (injected intraperitoneally) at a dosage of 50 mg/kg, given daily for 79 days, resulted in a significant decrease in the TSH level and a significant increase in the T3 and T4 levels in the rat's blood [17]. Another earlier investigation showed that oral administration of Sio2NPs at a daily dose of 1.500 mg/kg for 90 days resulted in a notable increase in the T4 level in the rat's serum, while the levels of TSH and T3 remained unchanged without any significant alteration [18].

A study has discovered that the physical and chemical characteristics of nanoparticles (such as their surface area, size, generating oxidants, chemical properties, charge, solubility, shape, and extent of clustering) have the potential to affect their behavior in biological systems [19]. The observation of toxicity in the ionic form occurred when these substances bypassed biological barriers and entered cell membranes, ultimately interacting with intracellular structures [20]. Any substance or element that disrupts any step of iodine uptake in the production of thyroid hormones leads to a significant disruption in the feedback cycle and triggers changes in shape or structure, such as the development of tumors in the pituitary and thyroid glands [21]. In contrast, another earlier research demonstrated that when exposed to nanoparticles, there was a reduction in the levels of transcription encoding the TH-induced receptor [22]. However, in this research, the evaluation of the thyroid tissue sections in the control groups revealed a typical structure with follicles filled with colloidal material under microscopic examination (Fig 4). The thyroid tissue sections in all the treated groups exposed to varying doses and durations of SiO2 NPs exhibited distinct histological alterations.

The results obtained in this study showed that the Sio2NPs have adverse effects on the tissue of the thyroid gland. As was reported by a previous study, who noticed that nanoparticles could gain access to the body via various pathways, spread to most of the body organs, and accumulate in their tissues

including the thyroid gland [23]. The accumulation of these particles in the tissue may cause histological changes, blocking capillaries or changing membrane permeability resulting in potential health risks [24]. The preceding research indicated that the silver nanoparticle affects the functioning of the thyroid follicle, leading to observable changes in its physiological movement and histological characteristics. These changes include atrophy, unequal size and shape, degeneration, and abnormality caused by trauma and injury. This proves that the silver nanoparticle acts as an endocrine disruptor [25].

Another study showed that when rats were injected intraperitoneally with a 0.5 ml dose of Fe2Nio4Zn nanoparticle solution for 2, 7, and 14 days, it resulted in inflammation and enlargement of the thyroid follicle [26]. Another earlier study showed that rats were injected intraperitoneally with a single dose of K2Cr2O7 at a dosage of 60 mg/kg on the third day of administration, it resulted in hypothyroidism and damage to the thyroid tissue caused by hexavalent chromium Cr (VI) [27]. Cellular oxidative stress was increased and Cr (VI), resulting in thyroid toxicity [28], decreased antioxidant activity was also observed. Due to various characteristics of Sio2NPs like their size, shape, composition, and surface chemistry, they have the potential to improve cellular penetration and induce long-lasting oxidative harm to cells, organelles, especially mitochondria, and even DNA damage. Consequently, the mitochondrial activity of thyroid epithelial cells can be impacted by Sio2NPs, leading to a decrease in the production of cellular ATP. This reduction is critical as ATP is necessary for the synthesis and release of thyroid hormones [29]. When the thyroid follicle becomes inactive, the cells within it often appear flat or squamous in shape, and the follicle itself usually becomes enlarged with a lot of colloidal fluid. On the other hand, when the cells are highly active, they transform into a columnar shape and the amount of colloidal fluid within the follicle decreases significantly [25].

The main mechanisms affected the silica nanoparticles and caused damage in the thyroid gland tissue by increasing ROS production and thus inducing oxidative stress [30]. It was discovered that the extent of oxidative harm to large molecules in the thyroid tissue affected by cancer had risen [31]. The formation of reactive oxygen species (ROS) has both useful and detrimental implications as defense substances against microorganisms and can operate as signaling molecules for triggering physiological stress responses, culminating in cell death. Over time, an increase in ROS levels can negatively affect the structural and functional integrity of numerous biological organs [32]. In contrast, the emergence of reactive species may be linked to inflammatory reactions and events that induce genetic harm [33].

The finding of this study revealed that SiO2 NPs have a deleterious effect on female rats' ovarian function by altering the levels of ovarian hormones (E2 and P) in the blood serum and that this change increases with increasing dose and exposure time. The findings of the current research are consistent with a previous study that showed a significant reduction in the amount of the E2 hormone in female fish that were exposed to ZnoNPs at concentrations corresponding to 1/20 and 1/30 of LC50, respectively, for 4 days [34]. Another prior study in rats that were exposed to the cold nanoparticles for 4 hours per day and -10 OC for 2 weeks generated an essential fall in the levels of E2 and P hormones in the female rats [35]. A previous study demonstrated palladium nanoparticles (Pd-NPs) in female rats because of an essential reduction in the level of the E2 hormone and testosterone at doses of 0.12, 1.2, and 12 mg/kg [36]. During 28 days, it was observed in a separate study that the estrogen hormone levels in female rats decreased when they were exposed to intraperitoneal injections of 5 mg/kg of MoO3 NPs [37]. Yoosefi et al. (2015) stated that after injecting female mice orally via gavage with titanium dioxide nanoparticles at different doses (10 and 100 ppm) for 2 weeks. The outcomes have shown a significant reduction in the levels of estrogen and progesterone hormones in all treated experimental groups that were exposed to these two doses (10 and 100 ppm) of TiO2 NPs when compared to the control group. In addition, they concluded that TiO2 nanoparticles have a deleterious influence on the reproductive potential of female sex hormones by lowering pituitary gonadal-axis activity [38].

The current study differed with the earlier investigation, which revealed that Tio2NPs in rats after intraperitoneal injection generated a significant increase in the level of E2 and P hormone at doses (150mg/kg) for 5 consecutive days [39]. Hosseini et al. (2019) treated female rats with ZnO NPs at different doses (4, 8, 25, 50, 100, and 200 mg/kg) for 4 weeks. The outcomes revealed a highly significant rise in the levels of (E2) and (P) in all animals that were treated with a high dose of ZnO NPs when compared with the control group [40].

According to a previous study, nanoparticles (NPs) exposure may cause a change in the rate of sex hormone levels in the blood via an indirect effect on the hypothalamic-pituitary-gonadal axis or a straight outcome on the stimulation of secretory cells such as granule cells, theca cells, follicle cells, and the corpus luteum [41]. Another study noticed damage to the testicular and epididymal histological architecture and a reduction in the amount of sex hormone (testosterone) in male mice following intraperitoneal injection of SiO2NPs [42]. Furthermore, SiO2NPs cause oxidative stress and inflammation in male reproductive organs, as evidenced by decreased antioxidant activity (superoxide dismutase, SOD) and an increase in the lipid peroxidation marker [malondialdehyde (MDA)], which leads to cell demise. To put it another way, due to their size, these particles can collect in secretory cells and have a direct impact on hormone production and secretion in the ovary [43]. Another study by Hosseini et al. (2019) found that heavy metal buildup in the reproductive organs of female rats resulted in lower blood levels of progesterone and estradiol hormones [41].

In summary, nanoparticles can affect ovarian hormone secretion and the hypothalamic-pituitary-gonadal axis in two means: the first is through the passage of nanoparticles during the blood-brain barrier into the hypothalamus and secretory cells of the pituitary, causing changes in Gonadotropin-Releasing Hormone (GnRH), Luteinizing Hormone (LH), and Follicle-Stimulating Hormone (FSH) secretion, thus undermining the normal mechanism of positive feedback negative feedback of the hypothalamic-pituitary-gonadal axis, which causes ovarian estrogen and progesterone hormone output to be aberrant. The second route nanoparticles enter the ovaries is through the circulatory system, where they aggregate in granulosa cells and theca cells, affecting steroid genesis [43]. Thyroid hormone, on the other hand, has a receptor on the surface of the ovary; therefore, these hormones have a direct influence on the ovarian cells [44]. Thyroid hormones (TH), which play a vital role in ovarian follicular growth, maturation, and the maintenance of numerous endocrine activities, however, have an indirect effect on nanoparticles [45]. Therefore, the dysfunction of the thyroid hormone hurts the hormones of female ovaries [46].

5. CONCLUSION

According to the study, exposure to Sio2NPs at varying concentrations altered the thyroid gland's structure and function,

resulting in decreased levels of T3 and T4 and an increase in TSH, and structural, and functional in ovary changes characterized by a decline in E2 and progesterone. Which is the result of hypothyroidism may lead to impaired ovaries in addition to damaging their tissue.

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Conflict of interest

The authors declare that they have no conflict of interest.

Ethical Approval

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Author contributions

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