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Effects of Mosquito Coil Smoke Inhalation on Human Health

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1. Introduction

A mosquito coil is a mosquito repelling incense, usually shaped into a spiral, and typically made from a dried paste of pyrethrum powder. The coil is usually held at the center of the spiral, suspending it in the air, or wedged by two pieces of fireproof nettings to allow continuous smoldering. Burning usually begins at the outer end of the spiral and progresses slowly toward the centre of the spiral, producing a mosquito-repellent smoke. A typical mosquito coil can measure around 15 cm in diameter and lasts around 8 hours. Mosquito coils are frequently burned indoors in Asia, Africa, Australia and to a limited extent in other parts of the world, including the United States (WHO, 2005).

In 1996, the WHO report estimated the worldwide annual consumption of mosquito coils to burn approximately 29 billion pieces. In a study in Taiwanese households, the prevalence of burning mosquito coils is 45% (WHO, 1998). The consumers usually use mosquito coils for at least several months every year, cumulative effects from long-term exposure to the coil smoke may also be a concern. Despite the fact that mosquito coil smoke may have many potential adverse health effects, large populations in developing countries still use mosquito coils in their daily lives.

Although mosquito coils are recommended for outdoor use, or for use in semi-enclosed patios and porches, coils are often used overnight in sleeping quarters. As a result peoples are exposed to a chemically complex mosquito-coil smoke containing small particles (< 1 μm), metal fumes, and vapors that may reach the alveolar region of the lung.

Mosquito coils can be hazardous. In 1999, sparks from mosquito coils ignited a fire that swept through a three-story dormitory building at a summer camp in South Korea; 23 people, including 19 children, died in the blaze. The smoke generated from a burning mosquito coil is of certain health concerns – one burning mosquito coil produces the same amount of particulate mass (diameter up to 2.5 μm) as 75-137 burning cigarettes would; and the emission of formaldehyde from one burning coil can be as high as that released from 51 burning cigarettes.

2. Mosquito coil ingredients

Active ingredients found in mosquito coils may include:

- Pyrethrum - a natural, powdered material from a kind of chrysanthemum plant
- Pyrethrins - an extract of the insecticidal chemicals in pyrethrum
- Allethrin - sometimes d-trans-allethrin, the first synthetic pyrethroid

- Esbiothrin - a form of allethrin
- Butylated hydroxytoluene (BHT) - an optional additive to prevent pyrethroid from oxidizing during burning
- Piperonyl butoxide (PBO) - an optional additive to improve the effectiveness of pyrethroid
- *N*-Octyl bicycloheptene dicarboximide (MGK 264) - an optional additive to improve the effectiveness of a pyrethroid

The most common active ingredients in coils are various pyrethroids, such as allethrin, d-allethrin, pynamin forte and ETOC. Octachlorodipropylether (S-2) is sometimes used as a synergist or active ingredient and use of such coils exposes humans to some level of bis-chloromethyl ether (BCME) which is an extremely potent lung carcinogen. Although the U.S. Environmental Protection Agency (U.S. EPA) does not register S-2 for any use, some imported mosquito coils contain this chemical, but their use is illegal in the United States, moreover in places like India S-2 is not banned.

Other compounds, released during the burning of mosquito coils (aldehydes, formaldehydes, fine and ultrafine particles,benzene, benzo[a]pyrene, benzo[b]fluoranthene, benzo[k]fluoranthene are also classified by the U.S. EPA as probable human carcinogens.

3. Side effects for using mosquito coil

Burning mosquito coils indoors generates smoke that can control mosquitoes effectively. The smoke may contain pollutants of health concern. Breathing in too much smoke will increase the risk of asthma and cause persistent wheezing in children. These are formaldehyde, octachlorodipropyl ether and bischloromethyl ether.

The active ingredient in mosquito coils is Pyrethroid insecticides. Pyrethroids are mostly harmless to humans, but they can irritate the skin and eyes. Some people are allergic to them too. According to experts, mosquito repellent mats emit fumes that contain a substance called Allethrin and its products that may cause health hazards like cancer and complications in pregnant women. When inhaled, it may worsen asthma in individuals who suffer from the disease. In others, it may cause nausea, vomiting, diarrhoea and coordination difficulties. It is especially dangerous for infants, young children and pregnant women.

Formaldehyde is a colourless, flammable and strong smelling gas. Inhaling it could cause watery eyes, throat discomfort, coughing, wheezing, nausea and skin irritation. Also, it can cause nasal or sinus cancer and even leukaemia. The amount of formaldehyde released from burning one mosquito coil can be as high as smoking 51 cigarettes. Formaldehyde is not an ingredient of mosquito coils but a by-product of burning them.

Octachlorodipropyl ether, better known as S-2, is a pesticide banned by the US Environmental Protection Agency. When S-2 is burned, releases bischloromethyl ether, a strong and harmful chemical that causes lung cancer. According to a study by UC Riverside scientists, many mosquito coils – most notably those manufactured in Asia – often contain up to one percent BCME (which stands for bis[cloromethyl]ether, a chemical associated with the breakdown of S-2). BCME has been described as “the most potent lung cancer chemical ever

discovered." And lung cancer is just about the most deadly cancer known. In one Chinese factory where mosquito coils were manufactured, a large fraction of employees were dead within five years of starting their jobs. The cause? Lung cancer.

Researchers from the University of California at Riverside recently tested more than 50 mosquito repellant coils purchased in Indonesia and at several Asian markets in California, and found they contained varying levels of a pesticide, S-2, that releases cancer-causing particles when burned. Of more concern was that the researchers found S-2 in samples of mosquito coils purchased in California. S-2 shouldn't be in any products sold in the United States because it's banned by the U.S. Environmental Protection Agency either as a main or secondary ingredient, according to the study. Not surprisingly, the coil labels didn't disclose the presence of S-2.

4. Exposure to mosquito coil smoke may be a risk factor for lung cancer in Taiwan (Chen, 2008)

About 50% of lung cancer deaths in Taiwan in 2008 were not related to cigarette smoking. Environmental exposure may play a role in lung cancer risk. Taiwanese households frequently burn mosquito coil at home to repel mosquitoes. The hospital-based case-control study was done to determine whether exposure to mosquito coil smoke is a risk for lung cancer.

Questionnaires were administered to 147 primary lung cancer patients and 400 potential controls to ascertain demographic data, occupation, lifestyle data, indoor environmental exposures (including habits of cigarette smoking, cooking methods, incense burning at home, and exposure to mosquito coil smoke), as well as family history of cancer and detailed medical history.

Mosquito coil smoke exposure was more frequent in lung cancer patients than controls (38.1% vs.17.8%; $p<0.01$). Risk of lung cancer was significantly higher in frequent burners of mosquito coils (more than 3 times [days] per week) than nonburners (adjusted odds ratio = 3.78; 95% confidence interval: 1.55-6.90). Those who seldom burned mosquito coils (less than 3 times per week) also had a significantly higher risk of lung cancer (adjusted odds ratio = 2.67; 95% confidence interval: 1.60-4.50). Exposure to mosquito coil smoke may be a risk factor for development of lung cancer.

5. Mosquito coil exposure associated with small cell lung cancer: A report of three cases (Jie Zhang, 2015)

Mosquito coils, which are commonly used as residential insecticides in Asia, contain different concentrations of octachlorodipropyl ether (S-2) as a synergist or an active ingredient. As bis(chloromethyl) ether (BCME) is an extremely potent lung carcinogen that can be produced by the thermolytic degradation of S-2, contact with mosquito coils is likely to expose individuals to a certain level of BCME, and therefore increase the risk of lung cancer. However, the significance of exposure is uncertain, as clinical and epidemiological studies concerning mosquito coil users and workers are lacking. This study described three cases of small cell lung cancer treated at the Shanghai Pulmonary Hospital that were likely to be the result of exposure to

mosquito coils. All patients had worked in the mosquito coil manufacturing industry, with an mean occupational duration of 9.1 years, and presented with similar respiratory symptoms, such as cough and dyspnea. Upon diagnosis, no metastasis to other organs was identified in any of the cases. Subsequently, the three patients were treated with chemotherapy as well as radiotherapy in one case, however, all patients succumbed to the disease, with a mean overall survival time of 10.7 months. Contact with mosquito coils is likely to expose individuals to a level of S-2 that may increase the risk of SCLC (small cell lung cancer).

Case one

A 39-year-old male never-smoker presented to the Shanghai Pulmonary Hospital (Tongji University, School of Medicine, Shanghai, China) on March 6, 2008, with a productive cough that had been apparent for one month. Radiography (Fig. 1A) and computed tomography (CT) of the chest (Fig. 1B) revealed enlarged lymph nodes and a mass measuring 4.8×3.4 cm in the upper lobe of the left lung. Immunohistochemical analysis indicated that the tumor was positive for thyroid transcription factor 1 (TTF-1) and synaptophysin (SYN), but negative for cluster of differentiation (CD)5 and 6 (Fig. 4). The patient was subsequently diagnosed with SCLC, tumor-node-metastasis (TNM) stage T4N2M0 (IIIb). Following two cycles of chemotherapy with 100 mg/m2 etoposide and 75 mg/m2 cisplatin on days one to three of three-weekly cycles, the patient exhibited a complete response (CR) (Fig. 1C). The six cycles of chemotherapy were completed on September 13, 2008. In March 2009, CT revealed the presence of progressive disease (PD) (Fig. 1D) and second-line chemotherapy with 60 mg/m2 irinotecan on days one and eight of three-weekly cycles, was subsequently initiated. Due to a poor performance status, the patient proceeded to receive supportive care, but succumbed to the disease on August 17, 2009.

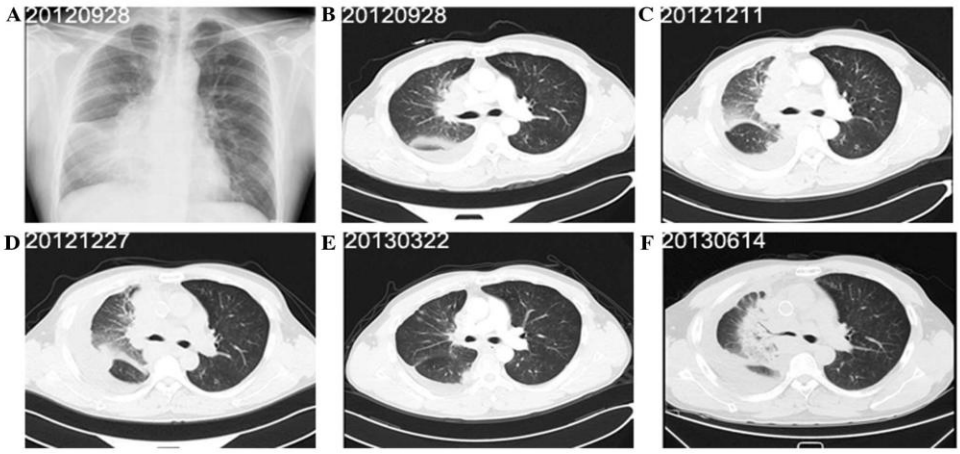

Figure 1 - Case one: Representative images from radiography and chest CT revealing the presence of a mass in the upper lobe of the left lung. (A) Radiograph prior to treatment. (B) Representative CT prior to treatment. (C) Representative CT image after two cycles of first-line chemotherapy. (D) Representative CT image showing progressive disease after six cycles of first-line chemotherapy. CT, computed tomography. (Jie Zhang, 2015)

Case two

A 41-year-old male presented to the Shanghai Pulmonary Hospital on October 20, 2010, with a productive cough and dyspnea. The patient had smoked 10 cigarettes per day for the past 20 years. Radiography (Fig. 2A and C) and CT (Fig. 2B) of the chest revealed enlarged lymph nodes and a mass measuring 10.5×7.2 cm in the upper lobe of the left lung. Immunohistochemical analysis indicated that the tumor was positive for TTF-1 and SYN, but negative for CD5/6 (Fig. 4). The patient was subsequently diagnosed with SCLC, stage T4N2M0 (IIIb). Following two cycles of chemotherapy with 100 mg/m2 etoposide and 25 mg/m2 cisplatin on days one to three of three-weekly cycles, the patient's condition deteriorated, with evidence of hemoptysis and thrombocytopenia. The patient succumbed to the disease on January 25, 2011.

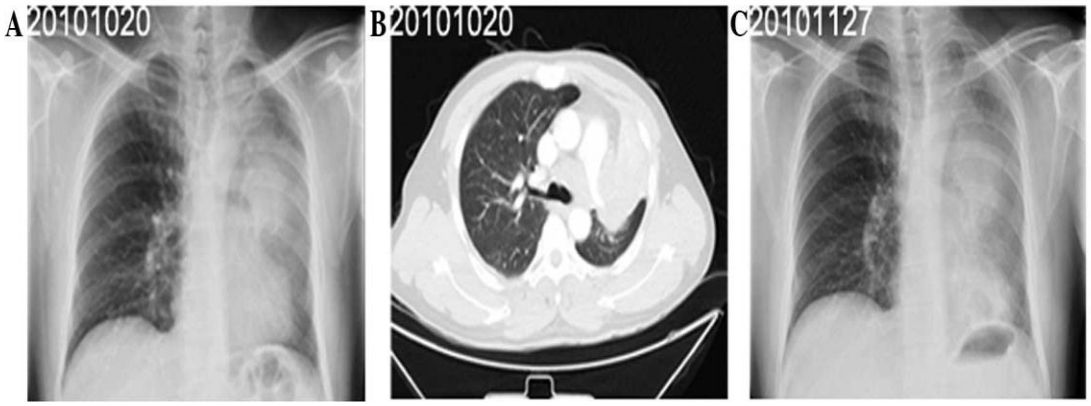

Figure 2 - Case two: Representative images from radiography and chest CT revealing the presence of a mass in the upper lobe of the left lung and enlarged lymph nodes. (A) Radiograph prior to treatment. (B) Representative CT image prior to treatment. (C) Radiograph after one cycle of first-line chemotherapy treatment. CT, computed tomography. (Jie Zhang, 2015)

Case three

A 40-year-old male presented to the Shanghai Pulmonary Hospital on September 27, 2012, with right-sided chest pain, a productive cough and dyspnoea that had been apparent for two weeks. The patient had smoked 15 cigarettes per day for the past 18 years. Radiography (Fig. 3A) and CT of the chest (Fig. 3B) revealed pleural effusion, enlarged lymph nodes and a mass measuring 9.4×8.0 cm in the middle lobe of the right lung. Immunohistochemical analysis indicated that the tumor was positive for TTF-1, NSE, chromogranin A and Ki-67, but negative for SYN, leukocyte common antigen, p63 and CD5/6 (Fig. 4). The patient was subsequently diagnosed with SCLC, stage T4N3M1a (IV). Following two cycles of chemotherapy with 100 mg/m2 etoposide and 25 mg/m2 cisplatin on days one to three of three-weekly cycles, the tumor response was assessed as PD (Fig. 3C). Superior vena cava stenting and 25 Gy thoracic radiation therapy (2.5 Gy/fraction) were performed in December, 2012 for two weeks. Four cycles of second-line chemotherapy with 60 mg/m2 on days one and eight of three-weekly cycles were

also administered (Fig. 3E). On June 14, 2013, the tumor response was evaluated as PD (Fig. 3F), at which time the patient's performance status deteriorated. The patient succumbed to the disease on July 02, 2013.

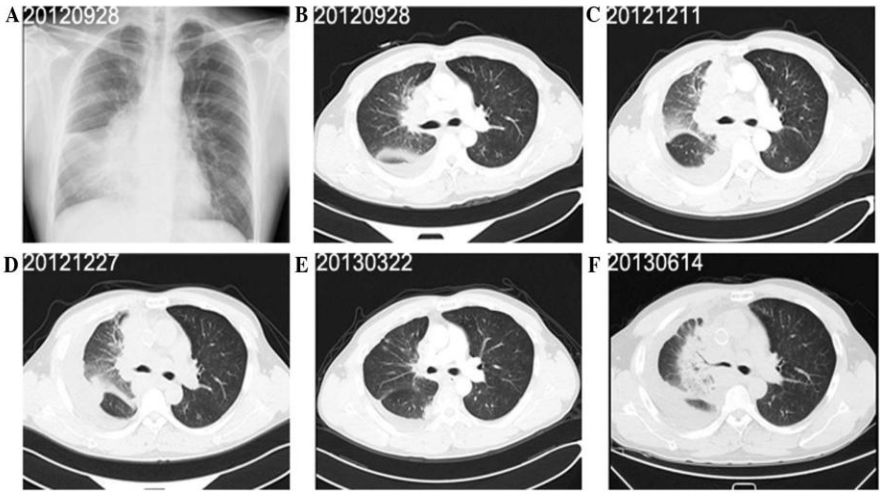

Figure 3 - Case three: Representative images from radiography and chest CT revealing the presence of a mass in the middle lobe of the right lung, pleural effusion and enlarged lymph nodes. (A) Radiograph prior to treatment. (B) Representative CT image prior to treatment. (C) Representative CT image after two cycles of first-line chemotherapy. (D) Representative CT image after superior vena cava stenting. (E) Representative CT image after thoracic radiation therapy and four cycles of second-line chemotherapy. (F) Representative CT image showing progressive disease after second-line chemotherapy. CT, computed tomography. (Jie Zhang, 2015)

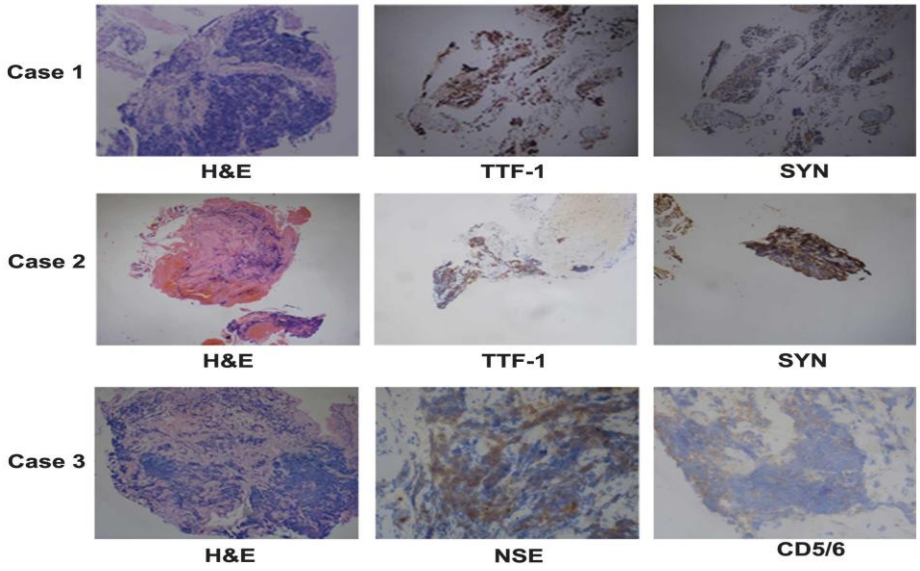

Figure 4 - Histological analysis of endobronchial biopsy specimens from cases one, two and three (magnification, ×100). H&E, hematoxylin and eosin; TTF-1, thyroid transcription factor 1; SYN, synaptophysin; NSE, neuron-specific enolase; CD, cluster of differentiation. (Jie Zhang, 2015)

Based upon the histological evidence, it was hypothesized that the inhalation of S-2 may have been the potential cause of SCLC in the three patients included in the present study. However, the other toxic products released following mosquito coil use have yet to be adequately assessed, therefore, future controlled studies should be conducted in order to evaluate their effects. Exposure is a controllable factor, and workers therefore deserve preventive actions in order to reduce exposure to toxins in the workplace. Furthermore, the effects of daily use and exposure to mosquito coils should be evaluated with respect to further health implications.

6. Toxicological Effects of Inhaled Mosquito Coil Smoke on the Rat Spleen:A Haematological and Histological Study (Garba, 2007)

Study on the effect of inhaling mosquito coil smoke on the haematology and histology of the rats spleen was carried out in the Departments of Human Anatomy and Human Physiology, University of Maiduguri, Nigeria between March and October, 2005. A total of 30 albino rats of the Wister strain were used in this study, they were divided into six groups of five rats each. Rats in Group I served as control (no exposure to mosquito coil smoke). While Groups II-VI were exposed to mosquito coil smoke for 12 h, 7, 14, 21 and 28 days, respectively. At the end of each experimental period, blood was collected from each rat for the analysis of Red Blood Cell (RBC) count, White Blood Cell (WBC) count, Haemoglobin (Hb) concentration, Packed Cell Volume (PCV) and the percentages of Neutrophils, Monocytes, Eosinophils, Basophils and Lymphocytes. The rats were then sacrificed and the spleen obtained, was processed for routine histological analysis. Haematological analysis of the blood obtained revealed a significant ($p<0.01$, 0.05) increase in WBC count in all exposure periods, while analysis of differential leucocyte count revealed a significant ($p<0.05$) increase in basophil and lymphocyte percentages. Histological analysis of the spleen tissue revealed severe congestion of venous sinusoids, hyperplasia and regression of both the red and white pulps. Results from this study demonstrates that mosquito coil smoke inhalation challenges the immune system in experimental rats, however, the precise mechanisms remain to be clarified in more detailed studies.

7. Toxic effects of mosquito coil smoke on rats: II. Morphological changes of the respiratory system (Liu, 1988)

Study on the toxic effect of mosquito coil smoke on the morphological changes of the respiratory system of rats was carried out in the Department of Anatomy, the Chinese University of Hong Kong in 1987. A group of 20 female albino rats was exposed to mosquito coil smoke, 8 h a day, 6 days per week, for 60 days. An additional group receiving air exposure served as control. The smoke-exposed animals had a lower body weight than the controls. Smoke-induced histopathological lesions, including an inflammation of the tracheal epithelium, atelectasis of the lung parenchyma, emphysema, increase of alveolar macrophages in the alveolar space and perivascular infiltration of polymorphonuclear cells were observed in the experimental rats. An elevation of enzyme activities of lactate dehydrogenase, glutamate pyruvate transaminase, glutamate oxoacetate transaminase and acid phosphatase were found in the serum of the smoke-exposed rats indicating the enzymes were released from the damaged tissues into the blood stream.

8. Mosquito Coil Smoke Inhalation Effects on Interstitium of Kidney of Albino Rats (Nazia Siddique, 2012)

The study was done in animal house of PGMI Lahore in 2012. Albino Rats were provided by Punjab University, Lahore. First step was acclimatization of rats, for which rats were kept in cages for 15 days. Average weight of rats was between 180-200gms. After acclimatization, the animals were randomly divided into three groups A, B and C having 8 rats in each. Group A served as a control so was not exposed to mosquito coil smoke while Group B and C were exposed to mosquito coil smoke for 8 hours/day. Group B were exposed to mosquito coil smoke for two weeks and group C for four weeks. Mosquito coil smoke was given as whole body inhalation.

Renal interstitium is the space present external to basal laminae of the kidney tubules. The renal interstitium consists of collagen fiber, macrophages and fibroblast. In kidney stroma cellular infiltrate, haemorrhage, congestion of vessels and fibrosis were observed in group B and C which was statistically significant when three groups were compared (Figs. 5,6,7,8) but absent in group A.

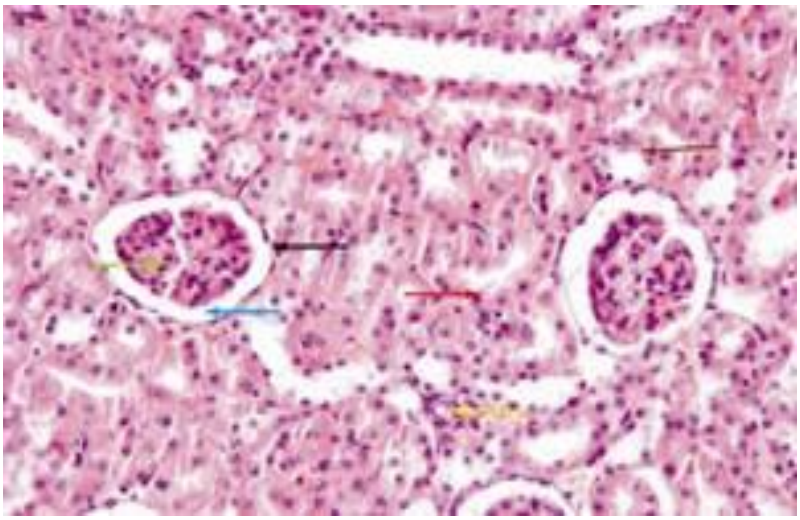

Fig.5. Photomicrograph of the kidney from the control group (A) showing renal corpusles lined by parietal squamous epithelium (black arrow) with central normal glomerulus (green arrow) surrounded by bowman's space (blue arrow). PCT lined by cuboidal epithelium with central nuclei (red arrow) with brush border. DCT lined by cuboidal epithelium (brown arrow). Normal interstitium with blood vessels also seen (yellow arrow). H&E stain X.200 (Nazia Siddique, 2012)

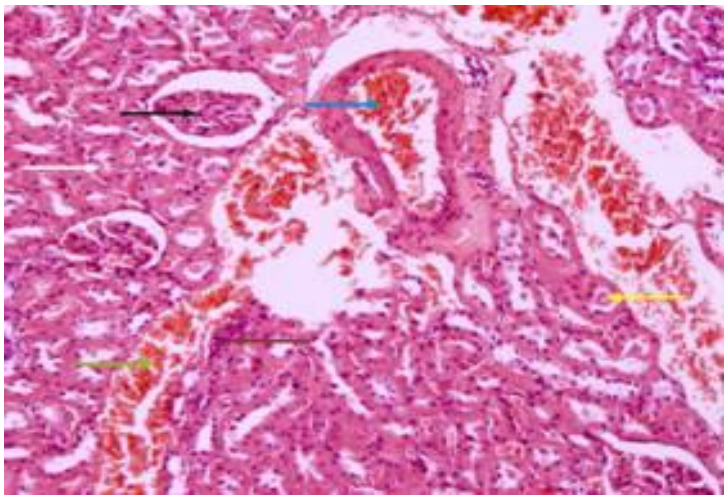

Fig.6. Photomicrograph of cortex of kidney from group (B) showing degenerated glomerulus (black arrow).There is necrosis of tubules (white arrow). Cellular infiltrates are seen (brown). In lumen of DCT protein cast is seen (yellow arrow). Interstitial hemorrhage (green arrow) and congested blood vessel (blue arrow) is seen. H&E stain X.100 (Nazia Siddique, 2012)

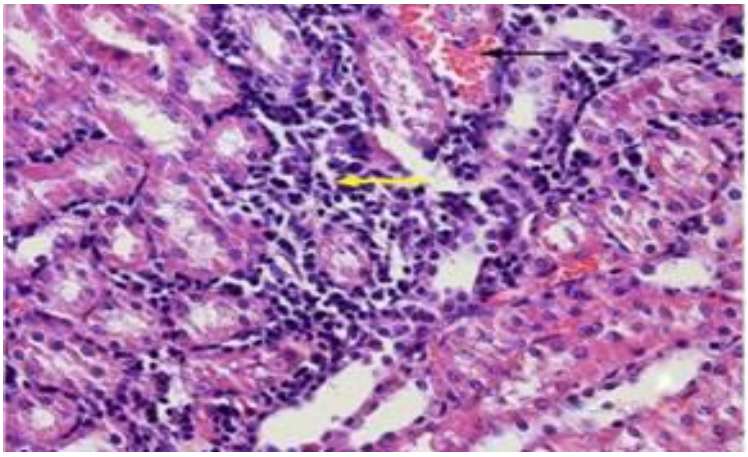

Fig.7. Photomicrograph of the kidney from the group C showing hemorrhage (black arrow) and cellular infiltrate (yellow arrow) in interstitium of kidney. H&E stain X.400 (Nazia Siddique, 2012)

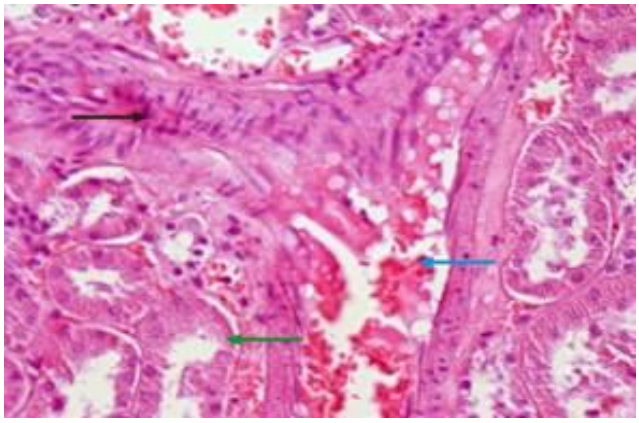

Fig.8. Photomicrograph of kidney from group (C) showing renal fibrosis (black arrow), congested blood vessel (blue arrow) and tubular necrosis (green arrow). H&E stain X.400. (Nazia Siddique, 2012)

The results of this study suggest that despite of being the least toxic pesticides, pyrethroids still have harmful effects, as exposure to pyrethroids can cause renal tissue damage . It is hoped that this study will produce an awareness and restricted use of pyrethroids insecticides especially at living places.

9. Conclusion

Some recent studies of mosquito coils in Asia and the United States have found an unlisted ingredient in unregistered mosquito coils available for sale from China. This chemical is called Otachlorodipropyl Ether or S-2, this is a synergist used in mosquito coils to increase the effectiveness of the active ingredient. While the active ingredient in mosquito coils, usually one type of Allethrin or another, is safe to humans, the S-2 synergist is highly dangerous to humans. When burnt by the smouldering mosquito coil S-2 degenerates into BCME, Bis (chloromethyl) Ether. BCME is an extremely potent lung carcinogen; some believe it to be the most potent carcinogen known. That is not to say all mosquito coils have this ingredient in them, most don't. If you do choose to use mosquito coils make sure they are approve for use in your country. In Australia, always check for an Australian Pesticide and Veterinary Medicine Authority (APVMA) approval number, this should be on the front of the box. This ensures the products are safe and approved for use.

In Philippines, the FDA advised the public to be cautious in buying mosquito coils that may contain hazardous substances. It said unregistered brands of mosquito coils are proliferating in the market. The use of mosquito coils may ward off diseases caused by mosquito bites. But the FDA said unregistered brands may be harmful to the public. Unregistered mosquito coils may not contain any active ingredient (AI) or may not contain the correct strength of the AI. In effect, it will not be able to ward off or kill mosquito that can bite the victim and, thus may transmit the infectious pathogen it carries. It noted that the safety of the active ingredient has not passed the evaluation and approval of the FDA. The active ingredient added in the mosquito coil in high

concentration can be hazardous to health when inhaled or accidentally ingested by children. It advised consumers to buy only mosquito coils that are registered with the FDA. The FDA said mosquito coils are designed for use in well-ventilated areas.

In Myanmar, the Food and Drug Administration (FDA) established since 1995, takes care of the safety and quality of Food, Drugs, Medical Devices, Cosmetics and Pesticides in the interests of public safety. Myanmar FDA informed the public that improper use of mosquito coils, mats cause liver damage, corner (in the eye) damage, Asthma, wheezing, shortness in breath, headache and loss of fertility in both men and women.

In the study conducted at the Taiwanese Institute of Medicine, it was found that a staggering fifty percent of the lung cancer deaths in Taiwan were not related to cigarette smoking, as it was previously thought to be. Instead, the deaths were reported from those households which frequently used mosquito coils. Pyrethrum is the major constituent of a mosquito coil. This chemical stings the mosquitoes in their eyes and makes them blind. But breathing in too much of Pyrethrum can increase the risk of asthma, wheezing and other serious lung disorders. Therefore the public should strictly follow the correct method of using them and avoid excessive use of mosquito coils.

Mosquito coils are to be used in an unenclosed environment. Though most of users want its maximum effect, they tend to close doors and windows while using this repellent, they forget its dangers. If you can't leave your windows and doors open, it is advisable to leave the room while the coil burns slowly and then come back and let air in before sleeping in such a room.

The mosquito coils must be lighted half an hour before bed time. It should be done, after closing doors and windows of the room and after switching off fans. After half an hour, all doors and windows should be opened and left open for some time, before closing them and going to bed. Only after that, the room is safe. Use special type of medicated net materials in the market that you can use to cover your windows and also use as mosquito nets at night. Using large mosquito nets is another successful method of preventing mosquito bit in the night. The nets made out of cotton wool or any similar material can be used with a fan to avoid excessive heat. Closing down doors and windows early around 5 pm or 5.30 pm will control the problem to a certain extent.

There are various types of mosquito traps available in the market now. There are many natural plants and leaves that can be used to chase away mosquitoes. There are many natural stuff such as 'Pengiri oil' that you can apply on your body without causing any health problems to avoid mosquito bites. Consume lots of garlic. Mosquitoes can't just stand the stuff. Apply Neem Oil to Your Skin. Neem oil is used as a natural insecticide. Neem oil is the best skincare product. Lavender Oil is commonly used as a mosquito repellent. The upside of it is the beautiful fragrance it carries. The fragrance is not going to attract mosquitoes.

The smoke from mosquito coil poses both acute and chronic health risks, you should avoid using them, starting from TODAY. Instead, prevent mosquitoes from getting into or breeding around your home, and use natural and safe mosquito eradication methods whenever necessary.

Safer alternatives include the use of indoor residual insecticide spraying and/or insecticide treated nets, clearing of bushes and drainage of stagnant bodies of water in your surroundings.

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