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Analysis of the Environmental Impact of Radiation Doses on Dental and Oral Diseases (K03.6, K05.1, and K05.3) in Workers in the Indonesian National Nuclear Energy Agency

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ABSTRACT

Gamma radiation has a significant influence on oral health disorders. The effects of ionizing radiation can cause tooth decay, due to a reduction in saliva production and changes in the oral environment that can increase bacterial growth leading to dental caries, and enamel erosion. The study aims to determine the relationship between exposure to gamma radiation dose and length of work on the incidence of dental calculus (K03.6) periodontal (K05.3) and gingivitis (K05.1). We also measured smoking behavior and history of diabetes mellitus as confounding variables. The type of research used is objective correlation, to determine the relationship of gamma radiation exposure to oral and dental diseases. The research design is a retrospective-reference period cohort, data collection is carried out on cases from 2017 to 2019. Based on the results of the analysis of radiation dose in 2019, there was a significant relationship between radiation dose and calculus formation with a value of (R=0.503 p=0.025). In 2018, dental calculus and gingivitis were significantly related, strong correlation, value (R=0.555 p=0.001). In 2019, the incidence of gingivitis and radiation dose, there is a strong correlation and is significantly related, to the value (R=0.507 p=0.021). Patients with a history of diabetes are very susceptible to periodontal and are not related to the length of work. It is recommended that radiation workers who have a history of diabetes and/or smoking take care of dental and oral conditions at least twice a year so that periodontal disease can be detected as early as possible.

1. INTRODUCTION

The emergence of nuclear technology has had good impact in various aspects. In addition to bringing great benefits, the use of nuclear power is known to have harmful effects on human health [1], the existence of deterministic or stochastic radiation effects, where these effects will affect certain organs or body tissues including the oral cavity [2]. Each irradiation of the whole body causes different effects on various tissues [3, 4]. For protection against stochastic effects, a dose limit value (DLV) is set, which is the separator between safety and danger. If the DLV is slightly exceeded, it indicates that there has been an error in radiation control. Health effects occur due to the interaction of ionizing radiation with the human body, starting the occurrence of events at the molecular level, which will develop into clinical symptoms, where the nature and severity of symptoms and the time of their occurrence depends on the amount of radiation dose absorbed and the rate of reception. A radiation worker is any person working in a nuclear installation or ionizing radiation installation, estimated to receive an annual dose exceeding the dose for the general public. The value allowed by the Nuclear Energy Regulatory Agency (BAPETEN) is required to be 20 mSv/5 years, and the general public is 5 mSv/5 years. Radiation worker dose monitoring is one way to ensure that the radiation worker dose limit value is not exceeded. Maintaining healthy teeth and supporting tissues in the oral cavity is important for radiation workers to maintain masticatory function and achieve optimal body health [5].

Oral health status can be assessed based on the status of the teeth, periodontal tissues, and others [6]. Periodontal disease (category K05) is a complex disease that affects various aspects of the supporting tissues of the teeth in a large proportion of the population worldwide. Lack of knowledge and understanding of the complexity of periodontal disease treatment causes many cases of periodontal disease to be left untreated, or dentists prefer to perform extractions. A healthy oral cavity is obtained by ensuring that all factors that can cause salivary acid pH are at normal levels [7, 8]. The presence of plaque and dental calculus (K03.6) in the oral cavity, in the

past and the present is often associated with poor oral hygiene and health because tartar can correlate with periodontal disease, resulting in further periodontal tissue damage and will have an impact on other body health [9, 10]. The main components of periodontal tissue are the gingiva, periodontal ligament, cementum, and alveolar bone. Each component is located in a different location but has the same function as tooth support tissue [9, 11, 12].

In 2016, the Global Burden of Disease Study stated that periodontal disease (category K05) is the 11th most prevalent condition in the world [11]. Previously in 2010, periodontal disease (category K05) was reported to be around 20-50% worldwide [12]. According to the 2018 Basic Health Research (RIKESDAS), the prevalence of the Indonesian population with unhealthy periodontal tissue disorders is very high, as much as 33.5% of 95%, occurring in the age group >30 years or adult group and decreasing at an older age >65 years [13]. The pathological state of the tooth-supporting tissue can occur due to the accumulation of dental calculus, plaque, systemic diseases, and smoking, all of which will correlate with the pathological state [14, 15]. Systemic diseases such as diabetes mellitus, can cause manifestations in the oral cavity including xerostomia commonly found in uncontrolled diabetes, gingivitis and periodontal, aphthous stomatitis (thrush) [16, 17].

One of the nuclear radiation rays produced is gamma. Gamma rays, which are a form of high-energy ionizing radiation, can contribute to periodontal damage through several mechanisms, especially when they are applied in head and neck radiotherapy or associated with radiation exposure focused on the oral area [18, 19]. Gamma rays can be damaging through the process of water radiolysis [20]. Gamma rays can interact with water molecules in periodontal tissues [21, 22]. This interaction results in water radiolysis, which produces highly reactive free radicals and ions [23]. These free radicals can damage biological molecules in periodontal cells and tissues. Gamma radiation has enough energy to damage DNA in periodontal cells. DNA damage can lead to genetic mutations and contribute to the development of oral cancer or other periodontal problems [24, 25]. In addition, exposure to gamma radiation can stimulate the release of inflammatory mediators in periodontal tissues. This can lead to localized inflammation that damages tissues and blood vessels [26, 27]. A decrease in blood flow to the periodontal tissues may also occur, reducing the supply of oxygen and nutrients necessary for the maintenance of healthy periodontal tissues.

The study aims to determine the relationship between exposure to gamma radiation dose and length of work on the incidence of dental calculus (K03.6) periodontal (K05.3) and gingivitis (K05.1) of the Pasar Jumat Nuclear Area of the Indonesian National Nuclear Energy Agency (BATAN) during 2017 to 2019. We also measured smoking behavior and history of diabetes mellitus as confounding variables. This study contributes to the impact of gamma radiation exposure on dental and oral diseases caused by.

2. METHOD

2.1 Research type and design

The type of research is objective-correlation, to determine the relationship of gamma radiation exposure to oral and dental diseases. The study design is reference period-retrospective cohort, data collection is carried out on cases ranging from 2017 to 2019. Dose variations were grouped into three, <1.27; 1.27 to 2.55; and >2.55 mSv. Meanwhile, the oral diseases identified were Dental calculus and Periodontal gingivitis. Research conducted at the Pasar Jumat Nuclear Area of the Indonesian National Nuclear Energy Agency (BATAN). Dose data was obtained from secondary data of personal Thermoluminisence Dosimeter (TLD) evaluation results. Ethical review of the study was conducted at the Indonesian National Nuclear Energy Agency (BATAN).

2.2 Sampling size and technique

The research sample was taken from radiation workers who came to the Pasar Jumat Nuclear Area Dental and Oral Clinic from 2017 to 2019. From the results of medical check-ups and medical records of patients who meet the inclusion criteria with a total of 300 subjects with purposive sampling technique. The criteria consisted of 101 female employees and 199 male employees. Age group <30 years as many as 52 people; 30 - 50 years as many as 120 people; >50 years as many as 128 people.

2.3 Analysis data

In this study, analytical tests were carried out using the SPSS program, for hypothesis testing with the Chi-square test. If the Chi-square assumption is not met, another alternative test (Krustal-Wallis) is used. For post-hoc use the Mann-Whitney test. Furthermore, it is seen whether it is significant the effect of radiation doses received by radiation workers who come to the Dental and Oral Clinic in the Friday Market Nuclear area of BATAN from 2017 to 2019 on the incidence of periodontal disease and other related variables.

3. RESULT AND DISCUSSION

The analysis was conducted on cases from 2017 to 2019 by classifying the gamma radiation dose into three, namely <1.55; 1.55-2.55; and >2.55 mSv. The doses were then tested for their influence on the incidence of dental calculus. The complete results are presented in Table 1.

Based on Table 1, the 2017 data shows radiation dose and dental calculus formation, are not significantly related, weak correlation value (R=0.59 p=0.698). In 2018, radiation dose and dental calculus formation are not significantly related, very weak correlation, value (R=0.101 p=0.417). In 2019, radiation dose and dental calculus formation, there was a significant relationship between radiation dose and calculus formation with a value of (R=0.503 p=0.025). Dental calculus was found in all dose groups, most at doses <1.27 mSv and 2.55 mSv, and a working period of >15 years, located supragingival. Radiation dose influences calculus formation, where the calculus can cause gingivitis. The period of dental calculus was not specifically mentioned, but in this research, it was found that exposure to gamma radiation from 2017 to 2019 could trigger the formation of dental calculus. High-energy gamma radiation can contribute to calculus formation by damaging tooth enamel and disrupting the mineral balance in the mouth, such as increasing calcium levels in saliva which can cause mineral deposits on the teeth [9, 28]. Damage to the enamel makes it more susceptible to bacterial plaque accumulation. Radiation can also affect the physical properties of bacterial plaque that adheres to teeth [29]. Certain doses of

radiation can make plaque more "sticky" to the tooth surface, making it more difficult to effectively remove by brushing or maintaining oral hygiene. However, this process will depend on the level of radiation exposure, the frequency of exposure, and the susceptibility of individual teeth to damage. Calculus that forms on top of the teeth can become a place for bacteria that cause gum disease (periodontal) to thrive [30, 31]. High radiation doses or repeated exposure may increase the risk of gum tissue damage, thereby increasing the risk of periodontal and further calculus formation [32]. Table 2 describes the relationship between dental calculus and periodontal disease (gingivitis) as follows.

Based on Table 2, the results show that dental calculus and periodontal disease (gingivitis) in each year show a significant relationship, and a strong correlation value (R=0.562 p=0.001). In 2018, dental calculus and gingivitis were significantly related, strong correlation, value (R=0.555) p=0.001). In 2019, dental calculus and gingivitis were significantly related and had a strong correlation, value (R=0.555 p=0.01). The presence of plaque and dental calculus in the oral cavity, in the past and the present is associated with poor oral hygiene and health, because dental calculus can correlate with periodontal disease, resulting in further periodontal tissue damage and impacting other body health [33-35]. The treatment component in gingival diseases such as gingivitis can be done by maintaining oral hygiene so that the gingivitis stage does not develop into Periodontal. The aim of treating periodontal disease by eliminating or suppressing the growth of supra- and subgingival pathogenic microorganisms mechanically and rinsing with antiseptic liquids [36, 37]. The following results of the analysis of the relationship between radiation dose exposure and the incidence of periodontal and gingivitis are presented in Table 3.

Table 1. Comparative statistical test results between radiation dose groups on dental calculus formation in radiation workers in 2017-2019

Year	Dose of Radiation (mSv)	*Dental Calculus* (K03.6)				Correlation
		Yes		No		
		n	%	n	%	
2017	<1.27	136	58.87	95	41.12	R=0.59 p=0.698
	1.27-2.55	33	62.26	20	37.73	
	>2.56	1	50	1	50	
2018	<1.27	88	41.12	126	58.88	R=0.101 p=0.417
	1.27-2.55	31	36.47	54	63.53	
	>2.56	2	33.33	4	66.67	
2019*	<1.27	166	58.45	118	41.54	R=0.503 p=0.025
	1.27-2.55	16	80	4	20	
	>2.56	1	100	0	0	

Table 2. Results of comparative statistical test of dental calculus on the incidence of gingivitis in radiation workers in 2017-2019

Year	*Dental Calculus*	*Periodontal Gingivitis Disease*				Correlation
		No		Yes		
		n	%	n	%	
2017	No	110	38.46	6	2.10	R=0.562 p=0.001
	Yes	44	15.38	126	44.06	
2018	No	114	37.38	7	2.30	R=0.555 p=0.001
	Yes	48	15.74	136	44.59	
2019	No	114	37.38	7	2.30	R=0.555 p=0.01
	Yes	48	15.74	136	44.59	

Table 3. Comparative statistical test results between radiation dose groups on the incidence of periodontal and gingivitis in radiation workers in 2017-2019

Year	Dose of Radiation (mSv)	Support Tissue Disease					
		Periodontal (K05.3)		Correlation	Gingivitis (K05.1)		Correlation
		n	%		n	%	
2017	<1.27	49	21.21	R=0.1 p=0.585	103	44.59	R=0.16 p=0.281
	1.27-2.55	10	18.87		28	52.83	
	>2.56	0	0.00		1	50.00	
2018	<1.27	43	20.09	R=0.064 p=0.672	98	45.79	R=0.063 p=0.61
	1.27-2.55	18	21.18		43	50.59	
	>2.56	2	33.33		2	33.33	
2019*	<1.27	60	21.13	R=0.234 p=0.395	128	45.07	R=0.507 p=0.021
	1.27-2.55	3	15.00		14	70.00	
	>2.56	0	0.00		1	100.00	

Table 4. Comparative statistical test results between working period groups on the incidence of periodontal and gingivitis in radiation workers in 2017-2019

Year	Working Period (Year)	Support Tissue Disease					
		Periodontal (K05.3)		Correlation	Gingivitis (K05.1)		Correlation
		n	%		n	%	
2017	<5	9	16.98	R=0.105 p=0.411	20	37.74	R=0.082 p=0.429
	6-10	3	17.65		6	35.29	
	11-15	9	20.93		25	58.14	
	>15	38	21.97		81	46.82	
2018	<5	4	6.90	R=0.536 p=0.001	24	41.38	R=0.105 p=0.294
	6-1	1	5.56		5	27.78	
	11-15	7	15.56		25	55.56	
	>15	51	27.72		89	48.37	
2019	<5	4	6.90	R=0.536 p=0.001	24	41.38	R=0.105 p=0.294
	6-10	1	5.56		5	27.78	
	11-15	7	15.56		25	55.56	
	>15	51	27.72		89	48.37	

Table 5. Comparative statistical test results between diabetes mellitus history groups on the incidence of periodontal and gingivitis in radiation workers in 2017-2019

Year	Diabetes Mellitus	Support Tissue Disease					
		Periodontal (K05.3)		Correlation	Gingivitis (K05.1)		Correlation
		n	%		n	%	
2017	normal	44	17.74	R=0.499 p=0.011	116	46.77	R=0.111 p=0.508
	controlled	6	30.00		11	55.00	
	uncontrolled	9	50.00		5	27.78	
2018	normal	47	17.87	R=0.475 p=0.012	124	47.15	R=0.06 p=0.708
	controlled	7	29.17		14	58.33	
	uncontrolled	9	50.00		5	27.78	
2019	normal	47	17.87	R=0.475 p=0.012	124	47.15	R=0.06 p=0.708
	controlled	7	29.17		14	58.33	
	uncontrolled	9	50.00		5	27.78	

Table 6. Comparative statistical test results between smoking habits groups on the incidence of periodontal and gingivitis in radiation workers in 2017-2019

Year	Smoking Habit	Support Tissue Disease					
		Periodontal (K05.3)		Correlation	Gingivitis (K05.1)		Correlation
		n	%		n	%	
2017	No smoking	38	17,12	R=0.395 p=0.017	102	45.95	R=0.019 p=0.89
	<2 pack	20	33,33		28	46.67	
	>2 pack	1	25,00		2	50.00	
2018	No smoking	40	17,17	R=0.394 p=0.015	111	47.64	R=0.003 p=0.982
	<2 pack	21	33,33		30	47.62	
	>2 pack	1	25,00		2	50.00	
2019	No smoking	40	17,17	R=0.394 p=0.015	111	47.64	R=0,003 p=0.982
	<2 pack	21	33,33		30	47.62	
	>2 pack	1	25,00		2	50.00	

Based on the results presented in Table 3, the radiation dose showed no significant relationship from 2017 to 2019, with a weak correlation value, (R=0.1 p=0.585), value (R=0.064 p=0.672), and value (R=0.234 p=0.395). The average dose received by radiation workers is 0.54-3.88 mSv / year, the incidence of periodontal disease is mostly found at doses <1.21 mSv. While the radiation dose with gingivitis (in 2017 and 2018) is not significantly related and the correlation is weak, the value (R=0.16 p=0.281) and the value (R=0.063 p=0.61). But for 2019 the incidence of gingivitis and radiation dose, there is a strong correlation but significantly related, the value (R=0.507 p=0.021). The absence of a relationship between radiation dose and periodontal is due to the uneven number of subjects in the dose grouping. The radiation dose received by radiation workers/year is still lower than the value permitted by BAPETEN of 20 mSv/5 years (4). Doses that tend to be low can occur due to various factors including complying with work procedures with radiation according to the required SOP. However, ionizing radiation, no matter how small the dose is, can cause ionization reactions in the subjected object, so that biological effects can appear [38, 39]. The results of statistical analysis between radiation dose and gingivitis showed a significant relationship. Radiation effects can affect the teeth, salivary glands, tongue, lips, and connective tissue in the mouth and cheeks [40]. If it affects the salivary glands, it can have an impact on the quantity and

quality of saliva produced, and there is a decrease in salivary pH [41]. Self-cleansing is reduced, affecting oral hygiene and resulting in abnormalities in the tooth-supporting tissues. By following the appropriate protocol for working in an irradiated place, it is hoped that it can minimize unwanted events. To prove the effect of tenure on periodontal and gingivitis, we tested it and the results are presented in Table 4.

Based on the results of the analysis in Table 4, shows that there is no significant difference, and the correlation is very weak (R=0.105 p=0.411). Periodontal and tenure with radiation sources, in 2017, were not significantly related, the value (R=0.105 p=0.411). In 2018, there was a significant relationship between, strong correlation values (R=0.536 p=0.001). Likewise in 2019, significantly related, strong correlation value (R=0.536 p = 0.001). The results of statistical analysis of Gingivitis and tenure with radiation sources in 2017, were not significantly related, the value (R=0.082 p=0.429), in 2018 the value (R=0.105 p=0.294) and in 2019 the value (R=0.105 p=0.294). There is no relationship between length of service and periodontal, this condition can occur because the number of subjects based on age is uneven. According to the literature, periodontal disease develops with age, with a longer working period it can be interpreted that the employee's age will increase [42, 43]. From the data above, it can be seen that periodontal is more dominant in radiation workers who work longer. This statement is by this studies, 2018 and 2019, there is a significant difference in the incidence of periodontal in the group of the working period with radiation sources, with a strong and significant correlation in the group of longer working period. While gingivitis is not associated with tenure [44, 45]. It is recommended that for radiation workers who work for >10 years, a detailed dental and oral examination is carried out including teeth, supporting tissues, and the condition of the oral cavity as a whole, regarding the results of panoramic x-rays [46]. Poor oral hygiene can affect periodontal tissue health, periodontal disease will correlate with increasing age and plaque accumulation. It can be assumed that with increasing age, a person's physical condition generally begins to decline if they do not adhere to a healthy lifestyle [47, 48]. In addition to measuring the tenure factor, we also measured the Diabetes mellitus factor which is one of the factors that can aggravate. The full results are presented in Table 5.

Based on the results of the analysis presented in Table 5, shows that the relationship is significant, in 2017 the value (R=0.499 p=0.011), in 2018 (R=0.475 p=0.012) in 2019 (R=0.475 p=0.012). Diabetes and gingivitis were not significantly associated, with a correlation value of (R=0.111 p=0.508). Gingivitis and diabetes are not significantly related, with a weak correlation value (R=0.060 p=0.708). In 2019, there was a significant relationship between the incidence of gingivitis and the diabetes group, with a strong correlation value (R=0.475 p=0.012). And there is no significant correlation between the incidence of gingivitis and diabetes mellitus, very weak correlation, value (R=0.060 p=0.708). In the incidence of periodontal disease with diabetes, only periodontal showed significant relationship results, while gingivitis had no significant relationship. Oral health status in patients with diabetes mellitus generally decreases, due to poor oral hygiene conditions, and the presence of diabetic angiopathy, causing oxygen supply to decrease and anaerobic bacteria to develop easily [49, 50]. Decreased phagocytic activity, reduced nutrition of tissue cells, or lack of antibody formation. Therefore, before the treatment of periodontal disease in patients with diabetes mellitus, antibiotics are given under certain condition [51]. In a study of 900 people without diabetes mellitus in the United States, it was found that as many as 817 people with diabetes mellitus, the number of people with higher levels of gingival disease was almost 2x greater than with type 2 diabetes mellitus [52, 53]. Or there is an association between diabetes mellitus and periodontal disease, namely gingivitis. The statistical results of the incidence of gingivitis in 2017 to 2019 differ from the above statement, namely that the incidence of gingivitis is not significantly different between diabetes mellitus groups with a weak correlation, the value of (R=0.11 p=0.508), (R=0.060 p=0.708) and (R=0.060 p=0.708). In addition to measuring the Diabetes mellitus factor, we also measured the smoking habit factor which is one of the factors that can aggravate. The full results are presented in Table 6.

Based on the results of the analysis presented in Table 6, shows that the relationship is meaningful, in 2017 the value (R=0.395 p=0.017), in 2018 (R=0.394 p=0.015) in 2019 (R=0.394 p=0.015). As for the relationship between Gingivitis and smoking, it is not significantly related and the correlation is weak, with a value of (R=0.003 p=0.982). In 2019, the incidence of Periodontal and smoking, there was a significant difference, a weak correlation (R=0.394 p=0.015). While for the relationship between Gingivitis and smoking, it is not significantly related, weak correlation, value (R=0.003 p=0.982). The observed variable is smoking habits, and the large number of cigarettes consumed by radiation workers can have an impact on the tooth-supporting tissue, both on soft tissue and hard tissue [54, 55]. Smoking causes manifestations in the mouth through the material contained in the smoke. One of the manifestations is abnormalities in periodontal tissue [40]. It turns out that the length of smoking plays a role in the occurrence of periodontal disease, namely periodontal. The habit of smoking and the number of cigarettes smoked >1 pack and <1 pack/day proved to influence the incidence of Periodontal compared to groups who did not have a smoking habit [45]. The incidence of Gingivitis is not always related to smoking habits and the number of cigarettes smoked [40].

4. CONCLUSIONS

Radiation dose affects calculus formation, where calculus that is overgrown with plaque and does not get treatment can cause abnormalities in periodontal tissue (Gingivitis or Periodontal), so early detection and treatment of dental calculus formation should be carried out in all radiation workers, to prevent periodontal disease. Only in 2019, there was a significant and strong correlation between the incidence of Gingivitis and radiation dose values (R=0.063 p=0.021). It turns out that the occurrence of Periodontal disease in radiation workers is obtained due to the length of work with radiation sources, not because of the radiation dose obtained and aggravated by the presence of systemic diseases. For Periodontal with Diabetes Mellitus, a significant relationship was found with a strong correlation in 2017, 2018, and 2019. The duration of smoking played a significant role in periodontal, but not in gingivitis for the three years of evaluation. Measurements are needed for other radiation wastes such as alpha and beta radiation to determine the risk of oral health.

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