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Concentrations of heavy metals in soil samples from dumpsites located at Kuje and Kwali area councils, Abuja, Nigeria

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Abstract
Heavy metal pollutions have been traced to poorly managed dumpsites. This study investigated the concentrations of some metals (Al, Cd, Cr, Cu, Pb, Mn, Ni and Zn) in soil samples from Kuje and Kwali solid waste dumpsites, Abuja, Nigeria. A total of 30 samples (12 from each dumpsite and 3 each from control sites: 2 km way) were randomly collected using soil auger (0-45 cm depth), processed and analyzed for each metal using atomic absorption spectrophotometer. The concentrations of metals were in the orders: Al > Zn > Cr > Mn > Ni > Cu > Pb > Cd and Al > Zn > Mn > Cu > Cr > Ni > Pb > Cd for Kuje and Kwali solid waste dumpsites, receptively. The control soil samples had significantly lower ($p>0.05$) metal contents. All the metals except Cd, Cr, Mn, Ni, and Zn were above the permissible limits stipulated by NESREA for Nigerian soils. Kuje dumpsites were highly contaminated by Ni (87.29), Cr (33.18), Pb (31.94) Cd (18.70), and Zn (8.72), unlike in Kwali dumpsite with very high pollution index only for Ni (44.70) and Pb (23.50). Strong positive correlations were recorded between Cr/Al, Mn/Cd, Zn/Al and Zn/Cu for Kuje dumpsite and Cr/Al, Cu/Al, Ni/Cu and Zn/Pb for Kwali dumpsite, indicating common accumulation by concerned metals in soil. This study suggest soil around Kuje and Kwali dumpsites are heavily polluted by Ni, Cr, Pb, Cd and Zn. Proper waste management and application of ecofriendly remediation actions are recommended to reclaim the polluted dumpsites.

1. Introduction

Generally, heavy metals are described as inorganic metallic elements and metalloids which are characterized by being above 5 g/cm^3 in density and possess serious health and environmental hazards at concentrations above certain thresholds. Those which are commonly mentioned and considered on daily basis include titanium, vanadium, chromium, manganese, iron, cobalt, nickel, copper, zinc, arsenic, molybdenum, silver, cadmium, tin, platinum, gold, mercury, and lead [1]. The rate of environmental pollution, particularly by heavy metals, has increased due to enhanced agricultural practices, rising metal-utilizing industries, and poor waste disposal practices, among others [1, 2]. As one of the most negative outcomes of global industrialization, heavy metals have been identified as unsafe environmental pollutant due to their special physicochemical properties, which makes them non-degradable and highly toxic [3]. Apart from their non-degradability and toxicity, heavy metals are predominant in soil which are mostly impacted by anthropogenic activities.

Dumpsite/landfills is an area that is set apart for waste disposal and management to prevent environmental pollutions due to indiscriminate dumping of refuse. According Fadili *et al*. [4] landfills/dumpsites, a major site created by humans for waste disposal and management, have been identified as focal point from which metal pollutants, among other hazardous materials, accumulate in soil. Of all the volumes of wastes, about 32 million tons are attributed to the quantity of solid wastes released in Nigeria with a population of over 170 million people [5]. The commonest forms of solid wastes are those from residential and industries sites. When these wastes are deposited at landfills/dumpsites, the organic materials undergo natural physicochemical and biological transformations or combustions to release varying concentrations of metals which are detrimental to organisms in the receiving environments [5]. In the receiving environment, most of these metals do not readily undergo chemical and biological transformation, and hence persist in the receiving environments for an unspecified number of years depending of the type and properties [1]. Hence, they pose serious challenges directly or indirectly to soil, water, air, plants, animals and humans [6-10].

Soil is one of the major recipients of heavy metals released via leachates from dumpsites. Heavy metals alters soil physical, chemical and biological properties and thus a serious concern to sustainable agricultural practices (FAO/1TPS, 2015) [11]. For instance, non-essential heavy metals like cadmium (Cd), mercury (Hg) and Pb, when they enter the soil, they are absorbed by the roots of plants and other soil biota, which ultimately affects the productivity, diversity and abundance of soil life [12, 13]. Pollution of the environment by heavy metals hinders the efficient activities of microbes, plants, animals, humans and agricultural ecosystem [14]. From the soil environment, some of them are migrate/leached into water bodies (surface/underground) where they contaminate drinking water sources [10, 15]. These sources, serve as express channel for serious threats to humans. In humans, short and long-term chronic meat toxicities reported [14]. These authors listed some of the serious disorders of heavy metals in humans to include cancer, skin defects, birth defects and impairments in functions of the kidney, nervous system, gastrointestinal tract, circulatory system, immune system, vascular system and apoptosis. The toxicity of the environments by the non-essential heavy metals cannot be overemphasized.

Several reports have been documented on varying concentrations levels of heavy metals in soil around dumpsites in Nigeria and other African countries [1, 2, 8-10, 13, 15-18]. The summary of these studies have shown that leachates from solid waste dumpsites/landfills are increasingly becoming the major route of elevated levels of heavy metals in soil and environs [2, 13, 15]. Consequently, environmental scientists have continued to beam their searchlights on studying the soil quality of dumpsite impacted soils in order to monitor and proffer solution(s) to the rising levels of inorganic chemical element and metalloid pollutions. Therefore, this study was designed with the aim of evaluating the concentrations heavy metals in soil samples collected Kuje and Kwali solid waste dumpsites within Abuja, Nigeria, with a view to further providing a baseline information against their environmental challenges**.**

2. Materials and Methods

2.1. The study area

The Federal Capital Territory (FCT), Abuja, Nigeria, is situated at the GPS coordinates of 9.0765 ^{o}N and 7.3986^{o} E with an area of 7,315 square kilometers and an estimated population of 3,564,100 in 2016. The East, West, South and North of FCT shares boundary with Nassarawa, Niger, Kogi, and Kaduna States, respectively (Figure 1). The average annual rainfall and high temperature of the FCT is about 806 mm and 32 ^{o}C, respectively. Abuja is becoming highly populated as a result of the rural-urban drift. As a results of the increasing urbanisation, industrial and anthropogenic activities, several solid waste dumpsites are being created at the various areas councils of FCT, Abuja. Kwali and Kuje area councils are two of the six major Local Government Area Councils in FCT, Abuja. Their geographical coordinates are 8°52’1” N, 7°0’18” E and 8°52’46.27’N, 7°13’39.22”E, respectively.

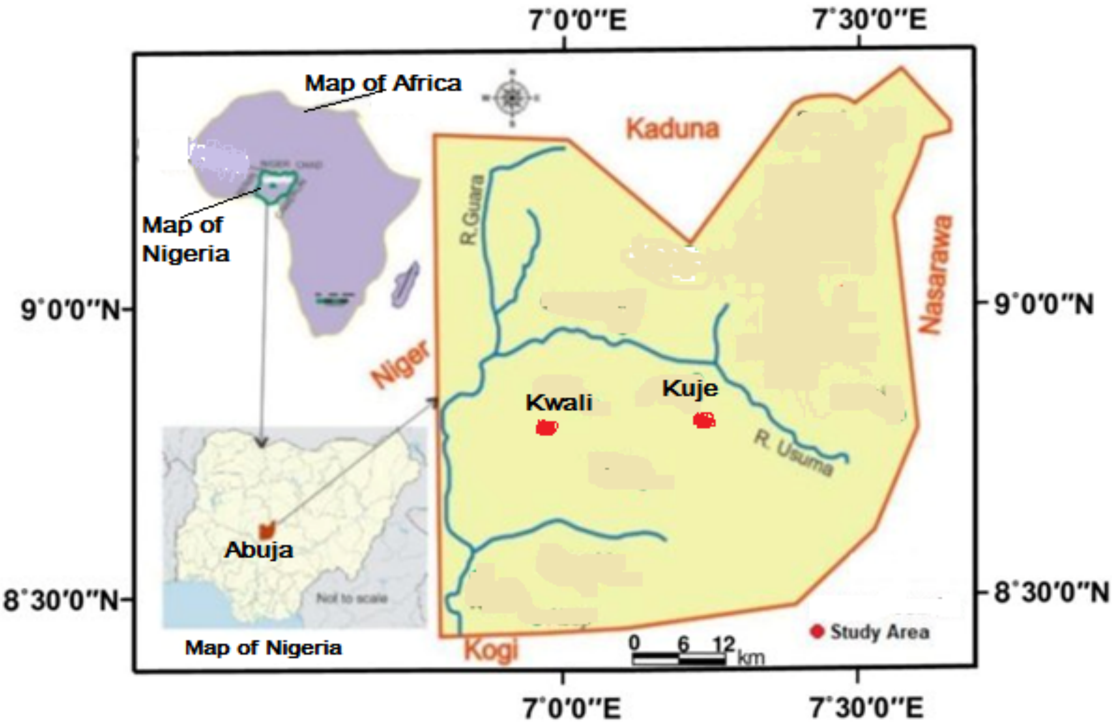

Figure 1: Location map of Abuja showing Kwali and Kuje area councils (study area)

2.2. Collection of soil samples from dumpsites

Prior to soil sample collection at the dumpsites, wastes were carefully cleared off. A total of 30 soil samples comprising 12 from different locations (10 m apart) within each solid waste dumpsites, and 2 km far away (where there were almost zero forms of anthropogenic waste generating activities) from each dumpsites (as control samples) were randomly collected using soil augers at a depth of 0-45 cm. All the samples were collected during the dry season, usually between November and March to prevent leaching of the inherent metals. All the soil samples were appropriately labeled and conveyed in sealed black polyethylene bags to the Laboratory for pre-treatment, digestions and analysis of heavy metal contents.

2.3. Pre-treatment of soil samples

At the Laboratory, the replicate soil samples for each site were mixed air-dried on work bench for some hours, gently pulverized with the aid of mortar and pestle before sieving using vibratory electronic sieve shaker to obtained evenly fine particles (2 mm).

2.4. Digestion of pre-treated soil samples

The digestion solution was made by mixing concentrated hydrochloric acid (HCl), tetrachlorate $HClO_4$ and trioxonitrate (v) acid (HNO_3) (3:3:1 v/v/v) [10]. Thereafter, 0.5 g of the dried pulverized soil samples was weigh using metler beam balance into a Teflon test-tube containing 25 mL of the digestion solution. The acid digestion process of the soil samples was done for 4 h at 220 °C. The cooled digested solution was then filtered using Whatman No 4 filter paper. The final volume of the filtrate was made up to 50 mL with HNO_3 (1 % v/v) prior to analysis of metals.

2.5. Analysis of metals in digested samples

The digest samples were analyzed for the concentrations of aluminum (Al), cadmium (Cd), chromium (Cr), copper (Cu), lead (Pb), manganese (Mn), nickel (Ni), and zinc (Zn) using atomic absorption spectrophotometer (AAS Buck Scientific Model 210) in accordance with the manufacture's guidelines for preliminary settings and operational conditions.

2.6. Determination of pollution index of each metal

The pollution or contamination index (*PI*) of each metal at the study location was estimated as a ratio between the metal concentration (*Mc*) and its reference metal value (*Rm*) (control soil samples) using the formula below:

$$PI = \frac{Mc}{Rm}$$

The levels of pollution or contamination by each metal was interpreted using the evaluation grading standards of the single-factor pollution index listed as follows: $PI < 1$, $1 \leq PI < 3$, $3 \leq PI < 6$ and $PI > 6$ to indicate low pollution, moderate pollution, considerate pollution, and very high pollution, respectively [19].

2.7. Data analysis

Data were analyzed in triplicates and the result values were presented as mean ± deviation. Descriptive statistics was employed to represent the data. The difference in mean of samples were analyzed using ANOVA at 5 % level of significance. Pearson's correlation matrix was used to determine the relationship between the metals using 1 % and 5 % levels of significance.

3. Results and Discussion

3.1. Concentration of heavy metals in soil samples

The concentrations of heavy metals in soil samples from soil waste dumpsites located at Kuje and Kwali area councils, Abuja (Table 1) revealed the presence of all the tested metals at varying concentrations. The order of heavy metal concentrations at dumpsites from Kuje and Kwali area councils was Al > Zn > Cr > Mn > Ni > Cu > Pb > Cd and Al > Zn > Mn > Cu > Cr > Ni > Pb > Cd. This result indicates that the highest and lowest metals in both study sites were Al and Zn and Pb and Cd, respectively.

Table 1: Concentrations of heavy metals in soil samples from dumpsites located at Kuje and Kwali area councils, Abuja

Metal	Kuje area council		P-value	Kwali area council		P-value
(mg/kg)	Dumpsite soil	Control soil		Dumpsite soil	Control soil	
Al	3757.00 ±14.36	5254.00 ± 21.14	0.000	1527.00 ± 21.32	3342.00 ± 17.45	0.000
Cd	18.70 ± 8.97	BDL	0.000	2.60 ± 0.61	BDL	0.000
Cr	564.00 ± 89.21	17.00 ± 9.78	0.000	46.23 ± 12.00	13.01 ± 0.98	0.000
Cu	46.88 ± 11.67	11.97 ± 6.67	0.000	65.69 ± 10.50	21.68 ± 8.85	0.000
Mn	334.00 ± 43.68	154.00 ± 52.43	0.000	174.00 ± 24.15	153.00 ± 43.87	0.042*
Ni	87.29 ± 16.75	BDL	0.000	44.70 ± 13.28	BDL	0.000
Pb	31.94 ± 12.99	BDL	0.000	23.50 ± 0.61	BDL	0.000
Zn	584.00 ± 202.00	67.00 ±11.78	0.000	417.00 ± 69.00	123.00 ± 18.00	0.000

Values are presented as mean ± standard deviation; BDL = below detectable limit;
**value significant at the 0.05 level*

A comparison of the levels of heavy metals in both study sites, as shown in Table 2, revealed that soil samples from Kuje area council were significantly higher ($p<0.05$) for Al, Cd, Cr, Mn and Ni. The concentrations of heavy metals at both locations were significantly higher ($p<0.05$) from their respective control sites (2 km way) except for Al and Mn ($p>0.05$).

3.2. Pollution index (PI) of heavy metals

Findings from the pollution indices for each metals at both study sites are presented in Table 3. Based on the pollution indices (Michael *et al.,* 2018), Kuje area council dumpsite soil was highly polluted or contaminated by Ni (87.29), Cr (33.18), Pb (31.94) Cd (18.70), and Zn (8.72), while The soil from Kwali area council dumpsite was very highly polluted by both Ni (44.70) and Pb (23.50). Both study locations had moderate and low contamination levels of Mn (2.17) and Al (0.72) respectively.

Table 2: Comparison of heavy metals in soil samples from dumpsites located at Kuje and Kwali area councils, Abuja

Heavy metals	Kuje area council dumpsite	Kwari area council dumpsite	P-value
Al	3757.00 ±14.36	1527.00 ± 21.32	0.012*
Cd	18.70 ± 8.97	2.60 ± 0.61	0.000*
Cr	564.00 ± 89.21	46.23 ± 12.00	0.000*
Cu	46.88 ± 11.67	65.69 ± 10.50	0.278
Mn	334.00 ± 43.68	174.00 ± 24.15	0.001*
Ni	87.29 ± 16.75	44.70 ± 13.28	0.032*
Pb	31.94 ± 12.99	23.50 ± 0.61	0.061
Zn	584.00 ± 202.00	417.00 ± 69.00	0.082

**values are significant at the 0.05 level*

Table 3: Pollution index (PI) of heavy metals in soil samples from dumpsites located at Kuje and Kwali area councils, Abuja

Metal	Kuje area council dumpsite		Kwali area council dumpsite	
(mg/kg)	PI	Contamination level	PI	Contamination level
Al	0.72	low	0.46	low
Cd	18.70	Very high*	2.60	moderate
Cr	33.18	Very high*	3.55	Considerate
Cu	3.92	Considerate	3.03	Considerate
Mn	2.17	Moderate	1.14	Moderate
Ni	87.29	Very high*	44.70	Very high*
Pb	31.94	Very high*	23.50	Very high*
Zn	8.72	Very high*	3.39	Considerate

Key: $PI < 1$, $1 \leq PI < 3$, $3 \leq PI < 6$ and $PI > 6$ to indicate low pollution, moderate pollution, considerate pollution, and very high pollution, respectively [10].

3.3. Correlation analysis

Tables 3 and 4 display the analysis of the Pearson's correlation matrix of heavy metals in soil from dumpsites located at Kuje and Kwali area councils, Abuja, Nigeria. It was observed that some of the heavy metals demonstrated positive and negative correlations with each other at $p<0.01$ and $P<0.05$ as the case may be. A strong positive correlation value was recorded between Cr/Al, Mn/Cd, Zn/Al and Zn/Cu in soil from dumpsites located at Kuje area councils, Abuja. While a relatively strong negative correction value was observed between Pb/Ni is same dumpsite. For the soil samples from dumpsites at Kwali area councils, Abuja, strong positive correlation value was found between Cr/Al, Cu/Al, Ni/Cu and Zn/Pb.

Table 4. Pearson correlation coefficient matrix of heavy metals in soil from dumpsites located at Kuje area councils, Abuja

	Al	Cd	Cr	Cu	Mn	Ni	Pb	Zn
Al	1							
Cd	-0.015	1						
Cr	0.447	-0.552**	1					
Cu	0.793*	0.033	0.547**	1				
Mn	0.063	0.955*	-0.691**	-0.023	1			
Ni	0.656**	0.413	0.145	0.253	0.450	1		
Pb	-0.250	-0.432	0.457	0.307	-0.606**	-0.741*	1	
Zn	0.941*	-0.134	0.447	0.889*	-0.058	0.3689	0.019	1

**Correlation is significant at the 0.01 level (2-tailed); **Correlation is significant at the 0.05 level (2-tailed).*

Table 5. Pearson correlation coefficient matrix of heavy metals in soil samples from dumpsites located at Kwali area councils, Abuja

	Al	Cd	Cr	Cu	Mn	Ni	Pb	Zn
Al	1							
Cd	0.121	1						
Cr	-0.717*	0.464	1					
Cu	0.816*	0.157	-0.482	1				
Mn	-0.290	0.385	0.404	-0.696**	1			
Ni	0.516**	0.376	-0.012	0.880*	-0.626**	1		
Pb	0.290	0.252	-0.411	0.410	-0.372	0.239	1	
Zn	0.447	0.333	-0.522**	0.280	0.004	0.002	0.879*	1

*Correlation is significant at the 0.01 level (2-tailed); **Correlation is significant at the 0.05 level (2-tailed).

4. Discussion

4.1 Concentration of heavy metals in soil samples

The significantly higher concentrations of majority of the heavy metals at both dumpsites than at the control could be connected with the higher contents of heavy metal-containing waste materials at dumpsites which must have leached into the underlying soil environment. It is a reflection of the intense levels of anthropogenic influence from the environment. This is line with recent results by earlier studies on the concentrations heavy metals around dumpsites [2, 17, 20]. The metal concentrations of the Cd, Ni and Pb were below detectable limits in control samples from both study sites, indicating that the solid wastes must have impacted heavily on their concentrations at the dumpsites. The National Environmental Standards and Regulations Enforcement Agency (NESREA) in conjunction with the Food and Agricultural Organization/World Health Organization (FAO/WHO) stipulated the permissible limits for Al, Cd, Cr, Cu, Mn, Ni, Pb, and Zn as 10,000 – 300,000 mg/kg, 3 mg/kg, 100 mg/kg, 100 mg/kg, 200 mg/kg, 70 mg/kg, 164 mg/kg and 421 mg/kg, respectively [21, 22]. Findings from this study indicates that Cd, Cr, Mn, Ni, and Zn were above the permissible limits stipulated for Nigerian soils at Kuje area council dumpsite. While for Kwali area council dumpsite, only Zn was above the limit. High concentrations of Cd, Cr, Mn, Ni, and Zn at the dumpsite could be linked to anthropogenic and industrial solid wastes released and disposed from leather tanning, paper mill, printing and photography industries, composted animal manure, agrochemicals and fertilizer waste, batteries, glass, metal alloys and ceramic materials in the dumpsites [17]. The relatively lowered concentration of Al in dumpsites than in control site suggest little impact from anthropogenic input than lithogenic input. Similar findings were reported previously [17]. Generally, the range found for heavy metals in Kuje area council dumpsite was lower than those observed for Kwali area council dumpsites in this study. This might be due to the variations in age of dumpsite, volume and type of waste materials as previously documented [2, 23]. The environmental and health importance of these metals: Cd, Al, Pb, Cr, Mn, Ni, Cu and Zn, cannot be over-emphasized. [1]. According to literature, Cd and Pb are heavy metals with insignificant benefits to growth and nutrition of plants and animals [24, 25]. When consumed directly or indirectly through contaminated food, air, dust or water, they lead to Cd [24] and Pb poisoning especially in children which are exposed to lead-laden dust particles [25]. Chromium (Cr), especially chromium (IV), unlike chromium (III), can cause cancer and other health issues when they pollute the environment from wastes or industrial emissions [26]. Exposure to environmental pollution by Ni not only destabilizes the soil ecosystem, but have been reported to induce allergies, cancers of respiratory tract, kidney damages and heart failure [27]. Although, the metal, Mn and Cu are well known in supporting effective normal physiological activities in plants and humans, excessive intake via contaminated food and water could lead to manganese [28] and copper poisoning [29]. The metal, Zn, is common metal that play crucial enzymatic roles in cellular activities up to a particular threshold, above which can adversely affect general biochemical activities within living organisms and the ecosystem [25]. Generally high concentrations of these elements normally affect the normal growth and metabolisms of plants and indirectly affects different tissues, organs, and system of exposed humans and other animals. The findings from this study further lay credence to those of previous reports that solid waste dumpsites substantially impact on the levels of metals in the receiving soil environments [2, 13, 15-18, 30-32].

4.2. Pollution index (PI) of heavy metals

Assessment of pollution risk is an important indicator of the fate of heavy metals in the environment: how contaminated the environment is with respect to heavy metals. Based on the pollution indices Kuje area council dumpsite soil was highly polluted or contaminated by Ni, Cr, Pb, Cd, and Zn, while the soil from Kwali area council dumpsite was very highly polluted by both Ni and Pb. Both study locations had moderate and low contamination levels of Mn and Al respectively. These findings further buttress earlier submissions that anthropogenic and industrial solid wastes abound at the dumpsites in this study. It thus suggests that the heavily polluted dumpsites especially by Ni, Cr, Pb, Cd and Zn requires the application of ecofriendly remediation actions to reclaim most of the dumpsites. Findings from this study are in agreement with the study of Jiya *et al.* [9] who reported heavy pollution by Cu, Cr and Zn.

4.3. Correlation analysis

It was observed that some of the heavy metals demonstrated positive and negative correlations with each other at $p<0.01$ and $P<0.05$ as the case may be. A strong positive correlation value was recorded between Cr/Al, Mn/Cd, Zn/Al and Zn/Cu (Kuje area council, Abuja) and between Cr/Al, Cu/Al, Ni/Cu and Zn/Pb (Kwali are council, Abuja). While a relatively strong negative correction value was observed between Pb/Ni. According to previous report, negative correlations between metals indicates as one of the metal increases in the soil, while the other one decrease and positive correlations indicate all the metals of interest might accumulate concurrently in the dumpsite soil [17]. Hence, the strong positive interrelationship observed probably suggests that those concerned groups heavy metals dumpsites at Kuje and Kwali area councils, Abuja, might have originated from similar or common sources. It also indicates a closely related route of mobility and similar accumulation rate in the soil. This finding is in concordance with previous reports [33-35], who found a strong positive correlation in a few metals tested, but however, in disagreement with earlier works [19, 36], who report strong positive correlations to all the metals evaluated.

Conclusion

This study has shown that significant levels of concentrations of Al, Cd, Cr, Cu, Pb, Mn, Ni and Zn were found in both soil samples from Kuje and Kwali area council dumpsites within FCT, Abuja, Nigeria. All the heavy metals with the exception of Cd, Cr, Mn, Ni, and Zn were above the permissible limits stipulated by NESREA for Nigerian soils. The significantly higher contents ($p<0.05$) of heavy metals in the dumpsites relative to the control reference sites could be associated with high anthropogenic input except for Al, which was higher in control, and this suggest that decomposition of metal-rich solid wastes at the dumpsites might have enriched the receiving soils with the concerned heavy metals. Thus, soils within the vicinity of these dumpsites should be constantly monitored, and managed to avoid leachates mobility that will ultimately contaminate both surface and underground water bodies. Therefore, proper waste sorting/segregation and disposal techniques for heavy metals rich materials should be encouraged along with application of ecofriendly remediation to reclaim the polluted dumpsites.

***Conflict of interest**: The authors declare that there are no conflict of interests.*

***Compliance with ethical standards:** This study does not contain any repot involving humans or animal subjects.*

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