

Development Department

Chad Henry – City Planner
201 West Water Street Piqua, Ohio 45356
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(937) 778-2049

January 29, 2024

*** MEETING NOTICE ***

Please be advised that the Planning Commission meeting will be conducted on **Tuesday, February 11, 2024 at 6:00 PM** at 201 W. Water St. in the Commission Chambers.

Residents and others with interest in the agenda topics may attend the meeting or submit public comment on an item until noon on the day of the meeting by emailing piquapermits@piquaoh.gov. Public comments submitted by the date/time noted will be presented to the Planning Commission at the public hearing proceedings.

The agenda may be accessed by visiting the City's website using this link <https://piquaoh.gov/1614/Agendas-Minutes>.

Please contact this office if you have any questions pertaining to this notice.

A handwritten signature in blue ink that reads "Chad Henry".

Chad Henry
City Planner

**PLANNING COMMISSION AGENDA
CITY OF PIQUA, OHIO
6:00 PM – TUESDAY, JANUARY 14, 2025
MUNICIPAL GOVERNMENT COMPLEX
COMMISSION CHAMBERS – 201 W. WATER STREET**

CALL TO ORDER

Chair Comments – Opening Remarks

ROLL CALL – Clerk Calls the Roll

Meeting Minutes – January 14, 2024

OLD BUSINESS

1. RESOLUTION PC 02-25

A resolution to recommend the rezoning of the newly created parcel from Resolution PC 01-25 to “IH – Industrial Heavy”.

2. RESOLUTION PC 04-25

A resolution to recommend approval of a proposed ordinance to permit “backyard chickens”.

NEW BUSINESS

OTHER BUSINESS/ADJOURNMENT

**PLANNING COMMISSION MINUTES
CITY OF PIQUA, OHIO
6:00 P.M. – TUESDAY, JANUARY 14, 2025
COMMISSION CHAMBERS – 201 W. WATER STREET**

CALL TO ORDER

At 6:00 pm Chairman Bubp called the meeting to order and welcomed all in attendance. Mr. Bubp outlined the order of business and procedures that will be followed by the Planning Commission.

ROLL CALL

Members Present: Brad Bubp, Eddie Harvey, Terry Wright, Adam Seas, Micah Underwood

Absent:

APPROVAL OF MINUTES

The minutes of December 11, 2024, Planning Commission Meeting were approved 5-0 by voice vote. Mr. Seas made a motion to approve the minutes and Mr. Harvey seconded the motion.

NEW BUSINESS

Resolution PC 1-25 – Major Subdivision – Parcel N44-250148

Chad Henry, City Planner was present and gave the staff report, which recommend approval of a major subdivision with dedication for a 5.079 acre parcel.

Mr. Seas asked if there was a plan to put lithium-ion batteries on the site. Mr. Kevin Krejny, City of Piqua Utilities Director spoke as the applicant. He noted that this project was being led by Piqua Power, but the City currently does not have a Director. He continued that last year AES requested to work with Piqua Power on redundancy of the power system, which would require the addition of a substation in this location.

Valerie Mullikan, 5905 Hickory Clayton, asked questions regarding the development of the future substation. She also asked what a “major subdivision” is, which Mr. Henry answered.

Ms. Mullikan continued to ask Mr. Henry what requires the user to build a substation. Mr. Henry stated that it is zoned as IH Industrial Heavy, and AES would be considered a utility in the district. He noted AES would own the 5 acres that are being split and the city would have to authorize that sale. She wanted to know who is going to oversee the substation and make sure they are going to do what they say. Mr. Henry noted that AES would be required to meet all regulations for a substation through local, state, and federal law.

Mark Safreed 3111 Tecumseh Cr, stated that when the water plant was built he was never notified and was happy that he got the notification from the city for this project. He stated there is a mound currently

to help work as a barrier for noise and visibility. Mr. Safreed requested confirmation on whether the mound would stay and who would own it. Mr. Henry noted that when a permit is requested to build something on the lot split the mounding, landscaping, and lighting would be reviewed. He reiterated that the case currently being requested isn't requesting construction, only a lot split.

Mr. Safreed stated that when there is a lot of rain the rain rolls off the water treatment property onto his property. He voiced his concerns about previous drainage issues and felt AES should know that information prior to purchasing the property.

Mr. Seas asked if AES would be allowed to come in and cause a water issue. Mr. Henry noted that AES would be required to meet all EPA stormwater requirements, which include retaining all water on their site.

Jeff Grimes, 1512 Margene Drive, asked what the property is zoned as right now. Mr. Henry stated that the property is Industrial, but there is some question as to why the zoning map doesn't reflect the IH designation like other surrounding properties. He noted that in 2023 when the city redesigned the code-the map changed, and it was potentially a map error.

Mr. Grimes was concerned that AES wasn't present at the meeting. He noted concerns about water quality, the size of lot split, and concern about the price of the sale.

Nicolas Mahrt, 1433 Covington Avenue, stated he was concerned about the possible health effects. He asked if there was a visual of the substation so he could see if there were large towers with brights lights and bugs that come with those lights.

Mr. Krejny responded that south of town on 25A there is a substation with a fenced in area and he anticipated that this substation would be similar. He noted that generally the lighting is inward facing to allow work to be done at the substation.

Mr. Mahrt asked about noise including humming lines. Mr. Seas stated it is probably the generators they hear there. Mr. Krejny said there are already lines in this area. Mr. Mahrt noted his concern about the eagles and wildlife in that area and how he felt that this would be disrupting some wildlife habitats.

Mr. Wright asked that AES come to the meeting and answer questions that the public has about what they are doing on the site. He also asked if an environmental study had been completed. Mr. Bubb stated that all of those items would be completed once the property is split, sold, and brought back or approved for development.

Mr. Henry stated this is only a recommendation from the Planning Commission and the City Commission would make the final approval. Mr. Krejny stated the purchase will go before the commission, which will allow additional discussion.

Mr. Bubb stated that if people have additional concerns and want to present them to the City Commission they will have another opportunity to do so, as the Planning Commission is just a recommendation.

Mr. Bubb asked if there were any additional comments and there were not.

Mr. Bubb noted that his spouse worked for AES and abstained from voting due to a conflict of interest.

Mr. Underwood made a motion to approve the resolution. Mr. Seas seconded the motion. The resolution was passed with a 4-0 vote.

Resolution PC 02-25 – Zoning Map Designation - Parcel N44-250148

Mr. Henry gave the staff report, which recommended approval of a Zoning Map Designation of a 5.079-acre parcel. He noted that this request was necessary due to an unclear designation that was likely caused by a mapping error by the city.

Jeff Grimes, 1512 Margene Drive, stated that if there are no environmental studies completed how can we say that there are not impacts from electricity. Mr. Grimes noted all the uses he felt could be permitted in the IH district. Mr. Hinkelman noted that those uses were special uses, and would require additional approvals from the Planning Commission and City Commission. He also noted that those uses were not being requested.

Mr. Grimes continued that he had concerns about the source water protection area and allowing any development in it, and he noted that he believes that IH has to be 10 acres to be split.

Mr. Underwood asked if this was tabled, would AES be able to come in person to address questions by the citizens. Mr. Henry noted that AES isn't applying for anything at this time, and isn't the applicant, the City of Piqua is the applicant. He noted that if the city sells the property to AES, which will likely occur, there will be a public comment portion of the City Commission meeting that AES will be able to answer questions prior to the sale of the property.

Mr. Seas asked why it isn't currently zoned. Mr. Henry reiterated that in 2023 when the Development Code was adopted, this property wasn't clearly designated. It is clearly just a map error, but he felt having it clearly defined would be more transparent.

Mr. Grimes stated Commissioner Homan made a resolution that nothing like lithium battery burning can happen in the city again and if the city sells the land to AES, they wouldn't be subject to the rules to not burn batteries. He stated he feels this will impact the entire city negatively.

Alicia Lange, address not noted, stated that she agreed with Mr. Underwood asking for it to be tabled.

Mr. Seas asked Mr. Krejny if the site is in the water protection zone. Mr. Krejny stated that anywhere could feed our water sources, as we are not on a well system. He noted that he wasn't aware of any water protection zone being noted in Piqua. He continued that water is treated and comes from three different sources.

Nicholas Mahrt, 1433 Covington Avenue, stated he felt the item should be tabled. He felt there were health risks, notification wasn't big enough, and wanted to ask AES questions before someone approved the request.

Mr. Krejny stated the substation would bring more power into the city and make it more reliable with a stronger grid for our residents. He noted that as systems age, they need new infrastructure to support growth. Mr. Mahrt stated that the AES substation could be a battery burning 2.0 and the news stations would be in Piqua.

Mr. Underwood stated that he lost sight of the fact that we are not here to approve AES building a substation. He reiterated that the Commission has a case in front of it to provide a zoning designation to a property that isn't currently zoned but has IH zoning all around. He also reiterated that no matter what occurs this evening, AES will have to go before the city commission before they can build anything on the lot split. He noted that this was the city being transparent about what was coming and giving citizens time to discuss the case.

Mr. Seas stated that the purpose of the Commission is to "check off boxes" of whether a case meets the development code or not. He continued that the Planning Commission generally recommends something to the City Commission for their final approval. He stated the decision goes to the City Commission because they are the elected officials, and they make the final decision.

Mr. Hinkelman clarified that not all IH uses require special use approval, and therefore some uses would be permitted by right once the zoning designated. He noted that any development would still go through the permit process, but none of those items are being requested under PC02-25, only the designation of zoning on the property.

Mr. Mahrt said he felt that it should be tabled because people's property could be affected, and the Planning Commission should hear from them first.

A resident of 201 N. Downing, stated she wanted to understand how the Planning Commission works. She continued to ask what standards are reviewed when approving a case and how the Planning Commission makes their decisions. Mr. Bubp responded that the Planning Commission follows the Development Code and City Ordinances. The resident asked if they have a choice here, or if they just have to follow the codes. Mr. Bubp stated that they have to make a decision based on the development code and ordinances. Mr. Seas read the resolution aloud and told the resident that they are considering this resolution based on the codes and ordinances.

Mr. Henry stated that he is the applicant on this case, to try and bring to light this oversight. He noted that it potentially doesn't need to have Planning Commission recommendation, but he felt it should be clarified. He noted with a new law director, we may not have to do this in the future.

Kim Heisler, 1802 W. Parkway Drive, said that she would like to know why this couldn't be zoned something other than IH.

Mr. Hinkelman responded that it was Staff's understanding that the property is already zoned Industrial, like the old water plant property. He said the request was to make it abundantly clear that it was IH.

Ms. Heisler asked why this didn't meet the 10-acre standard. Mr. Hinkelman stated that she was discussing the Heavy Impact Industrial Use, which is different in the code from the IH Heavy Industrial Designation. If a property has one of the uses listed as heavy impact, that requires a special use, which would require a 10-acre size. This property isn't requesting any heavy impact uses, it is requesting non-heavy impact, which require substantially less, and this parcel split meets that requirement.

Mr. Mahrt asked if there is anywhere else the substation could be placed. Mr. Bubp stated that at this point we are looking at providing a zoning designation on a property, not the specific development of that lot.

Mr. Mahrt wanted to know what is next. Mr. Seas reiterated that the land was previously zoned industrial but that “light industrial” and “heavy industrial” weren’t differentiated. He also stated that the city could have done this administratively but wanted to bring it publicly and be transparent. Mr. Martz stated that his main concern would be for the residents that live there. He is worried about the animals out there and believes this should be tabled. He said there are a lot of voices in the crowd showing concern. He feels like sometimes you get into these things and open a can of worms that weren’t intended.

Mr. Wright asked just because the area around it was IH why we must leave it as that. He is concerned that maybe it shouldn’t be zoned that. He is worried about it around our water plant.

Mr. Bubp states that the water plant probably needs zoning as IH to be what it is. He states that the city has facilities there and require IH zoning.

Mr. Bubp asked if there were any additional comments and there were not.

Mr. Bubp abstained from voting due to conflict of interest.

Mr. Harvey made a motion to approve PC 02-25, seconded by Mr. Underwood. Mr. Seas and Mr. Wright voted nay. Mr. Harvey and Mr. Underwood voted yes. The motion failed.

Mr. Underwood made a motion to table the resolution. Mr. Seas seconded the motion. The motion was tabled with a 3-1 vote.

Resolution PC 03-25 – Zoning Map Designation – Parcel C06-032810

Mr. Henry gave the staff report, which recommended approval for an IH Heavy Industrial Zoning Designation of a 38.66 acre tract of land.

Mr. Bubp asked if the Planning Commission just approved this annexation. Mr. Henry noted that the Planning Commission previously approved a case for 300+ acres north of this property. This property is scheduled to be annexed into the community shortly.

Valerie Mullikan, 5905 Hickory Clayton, noted that she hopes this is approved because she would like to see more business opportunities for the City.

Nicholas Mahrt, 1433 Covington Avenue, asked for clarification on where this was located. Mr. Henry again noted the location of the request.

Kim Heisler, 1802 W. Parkway Drive, asked if there was anything the city could do to disrupt someone from harming citizens. She asked if there was a standard or code that would allow the city to go after someone if something happens that harms the city. She stated that she felt there should be more oversight.

Mr. Bubp asked if there were any additional comments and there were not.

Mr. Seas made a motion to approve the resolution. Mr. Harvey seconded the motion. The resolution was passed with a 5-0 vote.

Resolution PC 4-25

Mr. Henry gave the staff report and noted that this language was drafted by Commissioner Simmons and requested to be brought to the Planning Commission as is for consideration. He noted that he wrote multiple resolutions to allow freedom of how the Planning Commission could move forward.

Mr. Hinkelman noted that this is the third time that he could find that language was submitted or proposed to allow chickens within the City of Piqua. He noted the language that is currently proposed is much different than the language that was recommended by the Planning Commission, but ultimately voted down by the City Commission in 2023.

Valerie Mullikan, 5905 Hickory Clayton, stated that she agreed with six laying hens in town, but opposed allowing the processing of chickens to eat on residential property. She also noted her concern about residential backyard chickens eggs being sold, as she noted increased liability for the sellers if people get sick from those eggs. She noted her support of chickens in general, but wanted to see some changes to the language proposed.

Jim Vetter, 714 S Downing Street, who was present representing the Southview Neighborhood Association. He stated that he is opposed to chickens in the residential areas of the City of Piqua. He believes that it could degrade the value of property in those areas. He noted concerns including noise, disease, manure and feathers, and additional rodents that could bring coyotes. He also noted his concern for the additional code enforcement activities that the city will have to do, which he felt was a waste of their time.

Alicia Lange, address not stated, stated that she has chickens but lives outside the city. She said she has never seen her chickens cause coyotes or other animals to come to her property. She felt that the cats and raccoons in the area are a bigger problem. She noted that she doesn't think people should have roosters in town, but that people should be able to have chickens.

Ms. Mullikan came back up and addressed the concerns about disease, avian flu, and predators attacking the chickens. She suggested people go to the OSU extension and get a poultry book and become more educated. She also stated chickens have a short life span of about 5 years.

Nicholas Mahrt, 1433 Covington Avenue, stated there have to be other communities that allow chickens and he is curious how those communities have handled this. He noted his support for local farmers and how people should support people selling eggs. He noted that supporting farmers is more important than any other issue at hand.

Kim Heisler, 1802 W. Parkway Drive, believes that chickens should be allowed. She stated that she thought chickens would add property value. She noted that dogs make noise and that manure can be used for gardens. She stated how she felt that more and more are taken away from citizens and code enforcement is subjective and retaliatory. She noted that she doesn't feel there should be permits or fees, nor inspections as they are subjective.

Mr. Vetter stated that some of the people speaking in favor of chickens do not live in town, and the other person that was in favor of them doesn't live in his neighborhood.

Mr. Bubp stated that chickens do smell and they do make noise. He felt the current language as drafted could be a potential nightmare for Piqua. He asked if you have to own the property to have chickens or if you can do it at a rental property. He asked about the second floor of a rental.

Mr. Seas stated that he is worried about people hitting chickens with their vehicles as they drive through neighborhoods if there isn't fencing.

Mr. Underwood stated that he wants chickens and is excited about this, as he feels like he wants to have them for his children. He noted that he doesn't think that hitting chickens would be a large concern and thinks we can figure it out as a community.

Mr. Seas stated that he would like to see more clear and developed regulations for chickens to make sure we don't have too many chickens or that properties are unkept or become a problem.

Mr. Wright stated that if the Commission voted for acceptance he agreed that owners should have some type of license or permit and proper insurance to help protect the egg sellers.

Mr. Hinkelman added that research was done in 2023, when language was presented previously, that shows that 20 subdivisions do not permit for the chickens in them. He noted that through deed restrictions or HOA standards, these areas specifically ban the raising of chickens. He continued that the City does not enforce HOA requirements, but HOA's will have a right to enforce their own regulations if they wish.

Mr. Hinkelman asked that the Commission allow clear regulations and a permit process allow the city to create a clear and fair process and enforcement of the program. He noted that whether someone is for or against the program clear regulations and permits protect those with chickens and those who do not wish to allow chickens in the community.

Mr. Underwood suggested a workshop to bring everyone together to talk about the option. Mr. Hinkelman asked that if it is tabled the board gives the city staff clear changes they would like to see so Staff can bring back updated language for consideration.

Mr. Wright asked if he could see Covington's ordinance for chickens. Mr. Hinkelman stated that it is publicly on Covington's website for review.

Mr. Bubp asked if there were any additional comments and there were not.

Mr. Harvey made a motion to table the resolution and provided multiple language changes for Staff to make regarding the legislation. Mr. Seas seconded the motion. The resolution was tabled with a 5-0 vote.

OTHER BUSINESS

None

ADJOURNMENT

With no other questions, comments, or business before the Planning Commission, a motion was made by Mr. Seas to adjourn the meeting seconded by Mr. Harvey to adjourn the meeting. With all those present in support of the motion, the meeting was adjourned at approximately 9:06 P.M.

The meeting minutes provided herein were prepared by Emily McCulla, City of Piqua Community Services Department. Comments requesting corrections, additions, or deletions to the content of this record should be directed to Ms. McCulla at emcculla@piquaoh.gov

STAFF REPORT

Planning Commission

Date: January 14, 2025
Re: PC 02-25 – Rezoning a newly created Parcel

Applicant: AES Ohio
Owner: City of Piqua

Address: 9801 SR 66
Parcel #: N44-250148

Zoning: Presently not zoned

Request: AES Ohio wishes to zone a newly created 5.079 ac. tract to “IH – Heavy Industrial”

Staff Comments and Recommendations:

Overview

The applicant, AES Ohio, has requested IH-Heavy Industrial zoning for the 5.079-acre tract to be subdivided from the City’s Water Treatment Plant (WTP) property, identified as Parcel Number N44-250148. This tract will be accessed via the Hardin Road cul-de-sac and is intended for industrial use consistent with the City’s zoning ordinance.

Staff Analysis

1. Zoning Compatibility:
 - The IH-Heavy Industrial zoning designation aligns with the use described in the City’s zoning ordinance. This includes facilities involving the manufacturing or storage of dangerous, noxious, or offensive materials, or those associated with smoke, odor, noise, glare, fumes, gas, vibration, fire or explosion risk, emission of particulate matter, radiation, or other disruptive factors.
2. Impact on Adjacent Properties:
 - The proposed zoning is consistent with the area’s industrial character and does not adversely impact adjacent properties or municipal operations. Adequate buffering and distance from sensitive uses mitigate potential concerns.

STAFF REPORT

3. Access and Infrastructure:

- The property's access via Hardin Road ensures suitable ingress and egress for industrial use. Existing infrastructure can support the zoning and use without requiring significant upgrades.

4. Conformance with Comprehensive Plan:

- The proposed IH-Heavy Industrial zoning supports economic development goals outlined in the City's Comprehensive Plan, which encourages industrial uses in areas suited for such activities.

Recommendation:

Staff recommends that the Planning Commission forward a **FAVORABLE** recommendation to the City Commission for approval of the IH-Heavy Industrial zoning designation for the 5.079-acre tract. This zoning classification aligns with the intended industrial use and complies with the City's regulatory and planning standards.

Conditions of Approval:

1. Any future development on the tract must adhere to applicable zoning and land use regulations, including performance standards for industrial activities.
2. The applicant must provide any necessary mitigation measures to minimize potential impacts on adjacent properties and the environment.

REFERENCES:

RECORD	PLAT	VOLUME	25,	PAGE	41
RECORD	PLAT	VOLUME	24,	PAGE	90
RECORD	PLAT	VOLUME	24,	PAGE	89
RECORD	PLAT	VOLUME	24,	PAGE	62
RECORD	PLAT	VOLUME	17,	PAGE	144
RECORD	PLAT	VOLUME	10,	PAGE	95
RECORD	PLAT	VOLUME	10,	PAGE	13

DEED RECORDS AS SHOWN

NOTES:

* THIS IS A PRELIMINARY SURVEY EXHIBIT FOR REVIEW BY THE PIQUA PLANNING COMMISSION.

* ACCESS TO THE NEW PARCEL IS TO BE GAINED FROM THE SOUTHEASTERN END OF HARDIN ROAD ALTERNATE (PRESENTLY A CUL-DE-SAC), THROUGH A JOINT ACCESS EASEMENT SHARED WITH THE CITY OF PIQUA.

* BASIS FOR BEARINGS: BEARINGS AND DISTANCES, SHOWN HEREON, WERE DERIVED FROM GPS OBSERVATIONS BASED ON GRID NORTH, OHIO STATE PLANE COORDINATE SYSTEM, SOUTH ZONE, NAD83 (2011), U.S. SURVEY FEET.

* OCCUPATION LINES GENERALLY AGREE WITH THE BOUNDARY LINES AS SHOWN.

* SURVEY MONUMENTS WERE FOUND IN GOOD CONDITION, FLUSH WITH GRADE UNLESS OTHERWISE NOTED.

* THIS SURVEY WAS PREPARED IN THE ABSENCE OF A COMPLETE AND ACCURATE TITLE SEARCH AND DOES NOT GUARANTEE TITLE.

* THIS PLAT REPRESENTS AN ACTUAL FIELD SURVEY PERFORMED IN NOVEMBER OF 2024 IN ACCORDANCE WITH THE MINIMUM STANDARDS FOR BOUNDARY SURVEYS AS INDICATED IN OHIO REVISED CODE RULE 4733-37-05. SAID SURVEY WAS OVERSEEN BY STEVEN L. SEESE, OHIO PROFESSIONAL SURVEYOR NUMBER 8895.

FLOOD STATEMENT:
ACCORDING TO F.E.M.A. MAP NO. 39109C0042F, DATED JUNE 5, 2020, NO PORTION OF THE SUBJECT PROPERTY SHOWN HEREON LIES WITHIN A SPECIAL FLOOD HAZARD AREA. THIS STATEMENT IS FOR INSURANCE PURPOSES ONLY AND IS NOT A GUARANTEE THAT THE PROPERTY WILL OR WILL NOT FLOOD.

Preliminary

11/22/2024 4:08:46 PM

STEVEN L. SEESE
PROFESSIONAL SURVEYOR NO. 8895



SHEET 1
OF 1

The logo for the Society of American Archivists (SAA) features a large, stylized 'S' in a dark blue color with a textured, wood-grain-like pattern. To the right of the 'S' are the letters 'A' and 'A' in a solid dark blue, followed by a trademark symbol (TM).

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email: info@sam.biz

PROJECT:	AES OHIO CITY OF PIQUA LLD
JOB NUMBER:	93322
DATE:	11-22-2024
SCALE:	1"=200'
SURVEYOR:	SLS
TECHNICIAN:	SLS
DRAWING:	93322-BDY
TRACT ID:	N44-250148
PARTYCHIEF:	JSS
FIELDBOOKS:	

Chad Henry

From: Bob Hartings <bobandlois76@gmail.com>
Sent: Monday, February 10, 2025 2:45 PM
To: Chad Henry
Subject: Re: Addition of AES Substation to the Water Supply Facility at 9300 St Rt 66

Chad...just a few more comments and few more questions.

If this substation is approved, does AES then intend to add more of those big transfer towers to carry the electricity into the city of Piqua?

It's just a bit upsetting that Washington Township has been a nice area with the Johnston Farm, all of the historical markers and the swift run and bike path areas being closeby to this proposed 5 acre area. The water facility was well done in its construction; the introduction of those big electric towers will, in my estimation, ruin the look of the area. It will not ruin the view for Piqua residents but for the residents of Washington township.

Wouldn't it be proper to include the township trustees in this discussion?

Thank you.
Bob Hartings

On Mon, Feb 10, 2025 at 11:41 AM Chad Henry <chenry@piquaoh.gov> wrote:

Bob,

AES has not submitted any project layout to the City of Piqua. Last month, we recommended that the City Commission approve the subdivision of approximately five acres from the existing water treatment plant parcel. While we informed the Planning Commission that AES intends to purchase the parcel for a substation, no plans have been provided.

Washington Township trustees do not review City of Piqua projects. If/when AES submits a development plan, we will review it for compliance with our

[Development Code](#).

Thanks,

-CH

Chad Henry

City Planner

Planning and Zoning Division

Community Services Department

937.778.2049 | www.piquaoh.gov



From: Bob Hartings <bobandlois76@gmail.com>

Sent: Monday, February 10, 2025 10:44 AM

To: Chad Henry <chenry@piquaoh.gov>

Subject: Re: Addition of AES Substation to the Water Supply Facility at 9300 St Rt 66

Thank you Chad. Hope that's OK. Please call me Bob.

My wife and I live on Reece Rd which is just a short distance from where this facility will be located. As I mentioned, the first notification of this change was from Facebook and the second came from a flyer left in our mailbox. I can understand the concern of the 2 property owners whose property is very close to this site.

1. My understanding is that there is an effort underway to have folks attend the Piqua City Council meeting tomorrow night.
2. Do you have pictures from AES of what the facility will look like? That might be helpful for all to better understand the impact for everyone. I would think that a smaller substation would not be an issue but 5 acres is a large tract with space for several very tall electrical transmission towers.

3. Are the Washington Township trustees included in this review? Should they be, if not?

Thank you!

Bob Hartings

On Mon, Feb 10, 2025 at 9:49 AM Chad Henry <chenry@piquaoh.gov> wrote:

Mr. Hartings,

You can view the Planning Commission case from January 14th at [this link](#). While AES has not submitted plans yet, my notes, the property subdivision, and the legal description are included.

- My review/recommendation starts on p. 5.
- The subdivision is shown on an aerial map on p. 9 and without on p. 10.
- The legal description is on p. 11.

Access will be from the cul-de-sac on Hardin Road, within the contiguous subdivision bordering the public road.

Thanks,

-CH

Chad Henry

City Planner

Planning and Zoning Division

Community Services Department

937.778.2049 | www.piquaoh.gov

From: Bob Hartings <bobandlois76@gmail.com>
Sent: Sunday, February 9, 2025 12:23 PM
To: Piqua Permits <piquapermits@piquaoh.gov>
Subject: Addition of AES Substation to the Water Supply Facility at 9300 St Rt 66

Hello Mr. Henry,

We have been alerted via Facebook and a flyer in our mailbox of the addition of an AES electric sub station and a city of Piqua utility substation at the above address.

Do you know where those planned facilities will be located in the attached Zillow map?:



The minutes mention access from Hardin Road. My understanding is that the neighbors to the North would bve most impacted. A picture is worth 1,000 words.

Thanks.

Bob Hartings

Neighbor North of this Facility

To Whom It May Concern,

My name is Richard Price, and I'm the owner of the property at 9911 Hardin Alt, Piqua, OH 45356. I have lived on Harden Alt for the past 10 years, and my family has resided there for four generations. When I moved to Washington Township, Hardin Alt was a quiet country road. Life changed for us when the land adjacent to us was annexed by the city of Piqua for the purpose of building a new water treatment plant. Recently, within the last week, we've been informed that AES plans to build two power substations on our road, one directly across the street and another literally 10 feet from my home's location on the property line. I have specific concerns regarding the effects of these substations on our health as well as on our property values. The effect that the water treatment plant has had on our day to day lives has been substantial; Possible re-zoning to heavy industrial and asking us to suffer the consequences of further utility development seems more than unfair and we believe this plan demands reconsideration.

In my personal interest, the health consequence of locating the substation so near to my home far surpasses any economic benefit to AES. I have been on Social Security Disability (SSD) for 10 years due to a severe immune deficiency illness that was likely caused by my work in the power generation industry. EMF radiation is acknowledged to be a cause of the disease that I have, and I'm strongly advised to avoid exposure to forms of radiation resulting from electrical power generation, as well as exposure to possibly harmful chemicals. I have no doubt that the close proximity of TWO substations is so dangerous to me that I would no longer be able to safely live in my home. In addition the added light will surely result in a total loss of darkness which adds to the Health ramifications to me and my surrounding neighbors. There are many documented studies showing the health risks associated to EMF radiation and sleep deprivation caused by industrial lighting.

The country lane that I had moved to has been radically changed by the water treatment plant, and we would like to avoid even further degrading of our lifestyle and property value. Where once we could see the stars, we have bright lights all night, every night. Trucks make chemical deliveries at 4-5 am, gate alarms go off, industrial noises like the never-stopping misaligned agitator chain and door alarms all disrupt our peace of mind. The change in water runoff and the local aquifer has affected our well, has caused issues with our foundation, and water floods our driveway and Piqua Alternate rd. with four inch puddles after any rain. The newly created cul-de-sac has become a major parking area for heavy equipment trailers when there are municipal projects in the area. A tree barrier designed to address the light and water issues failed to work as proposed on the initial water plant drawings; trees planted in barren gravel rarely do well. Although these issues may not seem germane to the question of the location of the substations, we feel that we have suffered more than our share of sacrifice for the sake of public utilities. Additionally, it's estimated that our property value may decrease by as much as 30% if surrounded by two substations. Again, how much more can we be asked to give up?

We would like to preserve as much of our natural surroundings as we can. For generations, my family had cared for the field and forest that became the water treatment plant, and we have a deep attachment to the lane. Piqua planted wildflowers in the field in question, and nature is beginning to come back. A nesting pair of Bald Eagles have established themselves there, as have Henslow Sparrows and a Northern Harrier. Rabbits, racoons, possum, fox, coyote, and a

major deer migration route all are visible in the area that may soon be dominated by two substations.

The decision to place these two substations where they're proposed may provide AES with an economic benefit, but couldn't these stations be placed in an undeveloped place nearby? There is a lot of undeveloped land on Rt 66 south of the water treatment plant that would not affect any homes and residents; why should our health be so seriously endangered? Why should our property values be further diminished? Why should my family and the families that live in Washington township carry this additional burden after the challenges posed by the addition of the water treatment plant? To me, it's clearly a matter of weighing my literal right to live against the corporate interest of placing substations in my lap.

P.S. I still find it curious that the three properties closest to this proposed site have not received any notification letter. Please send the next notifications via certified mail so we have a clear and proven method of notification. To be told by the city that people that are opposed to projects generally denied receiving notification doesn't really fly with me. I have attached my supporting documents as pertain to the environmental impact and health hazards associated with this project.

In addition I would like any further notifications to me as a property owner to be sent directly to my attorney therefor illuminating the possibility of confusion or future allegations, I have provided a link for Nate Fund:

[McCulloch Felger Fite & Gutmann Co LPA](#)

I thank you for your time.

Richard Price
9911 Hardin Alt
Piqua OH
305-849-4443

-The **Bald and Golden Eagle Protection Act** (16 U.S.C. 668-668d) is a [United States federal statute](#) that protects two species of [eagle](#). The [bald eagle](#) was chosen as a national emblem of the [United States](#) by the [Continental Congress](#) of 1782 and was given legal protection by the Bald Eagle Protection Act of 1940.

The purpose of the Bald and Golden Eagle Protection act is to not agitate the bald and golden eagle to the extent of not 1.) Abusing an eagle, 2.) Interfering with its substantial lifestyle, including shelter, breeding, feeding, or 3.) Nest abandonment.^[3] The eagle feathers have been collected and incorporated into clothing, art, jewelry, etc. In addition, having the possession, exchange, or sale of bald eagle feathers violates the act if no permit is obtained. The basic structure of the act resembles the [Migratory Bird Treaty Act](#).

-The **Endangered Species Act of 1973** (ESA or "The Act"; 16 U.S.C. § 1531 [et seq.](#)) is the primary law in the United States for protecting and conserving imperiled species. Designed to protect critically imperiled species from [extinction](#) as a "consequence of economic growth and development untempered by adequate concern and conservation",

[United States Fish and Wildlife Service](#)

- https://www.eca-usa.com/files/ECA-BaldEagleArticle_021913.pdf
- <https://www.fws.gov/media/national-bald-eagle-management-guidelines>
- ** https://www.fws.gov/sites/default/files/documents/national-bald-eagle-management-guidelines_0.pdf
- <https://www.brighthubengineering.com/power-generation-distribution/80636-what-are-the-health-risks-of-living-near-an-electric-substation/>
- <https://www.powerwatch.org.uk/elf/substations.asp>
- [Electric and Magnetic Fields from Power Lines | US EPA](#)
- <https://www.irjet.net/archives/V2/i3/Irjet-v2i379.pdf>
- <https://www.voltagelab.com/electrical-substation-safety-distance/>
-
- <https://www.epa.gov/radtown/electric-and-magnetic-fields-power-lines>
- [Electric and Magnetic Fields from Power Lines | US EPA](#)

- [light effects on health](https://pmc.ncbi.nlm.nih.gov/articles/PMC2627884/) , -<https://pmc.ncbi.nlm.nih.gov/articles/PMC2627884/>
- ***** - [https://www.ajpmonline.org/article/S0749-3797\(13\)00322-X/abstract](https://www.ajpmonline.org/article/S0749-3797(13)00322-X/abstract)
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- *****- <https://www.webmd.com/a-to-z-guides/news/20241022/why-scientists-are-linking-more-diseases-to-light-at-night>
- [https://www.ajpmonline.org/article/S0749-3797\(13\)00322-X/abstract](https://www.ajpmonline.org/article/S0749-3797(13)00322-X/abstract)

[These are the endangered species which have found refuge in the space provided by the city of Piqua.](#)

[** henslow sparrow](#)

[** northern harrier](#)

[** bald eagle](#)

- [get an emf survey for health reasons](#)

Environmental regulations that require assessments before constructing power lines. These assessments evaluate the potential impact on local ecosystems and wildlife. Residents should be aware of these regulations and participate in public hearings to voice their concerns.

-The disadvantages of living near power lines encompass a wide array of health, safety, and environmental concerns that cannot be overlooked. From potential health risks like increased cancer rates and neurological disorders to environmental impacts and safety hazards, the implications of residing in close proximity to power infrastructure are profound.

- Electromagnetic fields (EMFs) are produced by production, transmission, and use of electrical devices such as power lines, electrical wiring, transformers and electrical equipments, so each person in the society can be exposed to them [1]. Extremely low frequency (ELF) fields includes alternating current (AC) fields and other electromagnetic, and non-ionizing radiation from 3Hz to 300Hz [2]. Electric power substations, transmission lines, distribution lines, industrial devices as well as electric appliances are some of the commonly known sources of ELF magnetic fields in the environment. Since many substations are surrounded by residential or commercial areas, people living near them and also personnel working in the substations may be exposed to high ELF magnetic fields [3]. As a result, it is necessary to assess personal exposure to ELF magnetic fields and the effects of them [4].

—Recent studies have been done mostly on the health effects of exposure to non-ionizing low frequency radiation. It has been shown that different types of animals, and humans are sensitive even to minor exposure to electromagnetic fields [3,5]. Public concerns have been raised about possible effects of exposure to electromagnetic fields on human health and [2]. EMF can lead to rapid aging and have a significant impact on metabolic systems including elevated blood glucose levels, elevation in lipid levels, increased neuro regulatory disturbances, decreased testosterone levels in males and impacts on the Central nervous system (CNS), cardiovascular, and immune systems amongst other issues. EMFs have an effect on raised blood pressure, pulse rate and affecting other dynamics of cardiovascular function [6,7]. Recently, several studies reported that extremely low-frequency magnetic field exposure might disrupt normal sleep [2]. Asanova and Rakov were the first to note that occupational exposure to power frequency electric and magnetic fields might have a detrimental influence on night sleep. Akorstedt observed that magnetic field exposure was associated with a significant reduction in the duration of slow wave sleep (sleep stages III and IV) [8]. In 2009, Sharifi reported the prolonged exposure to magnetic fields of 230

kV high voltage substations can cause to increase the psychiatric disorders like sleep disturbance, despite that the exposure level was lower than occupational permissible limits (ICNIRP) [9]. Yousefi observed magnetic field exposure can exacerbate some psychological problems. He considered 103 workers in Tehran high voltage substations. The symptoms of depression, paranoia, intellectual and practical obsession, interpersonal sensitivity, anxiety, hostility, phobia and psychosis were observed based on questionnaire results [10].

To whom it may concern,

My name is Nicholas Brown, my wife, kids, and I are the property owners of 9937 Hardin Alternate Road, Piqua, OH 45356. We decided to purchase this property after spending the last 12 years living in town, for multiple reasons, but the main one being that it is a quiet, secluded country road and the perfect slice of peace for our kids to grow up on. Recently we have found out, in a not so pleasant way, that AES plans to build a power substation not even 50 feet from our home along with another substation placed directly across the street. I am typing this letter regarding our many concerns including our health, our safety, and our property value. You are asking not only us, but many families, to suffer major consequences for the sake of furthering utility development and that seems completely unjustified and unfair. We believe that this plan needs to be reconsidered and discussed with the people it negatively affects the most.

There are a number of issues that we have with this. To start, we found out about this possible AES substation when the company, SAM, that did the surveying for this possible purchase, spent a week, on and off, trespassing on our property. Not only were they trespassing on our property with nothing said to us and none of our questions answered about what they were doing, but they were also marking our yard with spray paint and flags. We have the right to know why people are consistently on our property, when not allowed by us. This problem led to us calling the City of Piqua to figure out what was going on. This is when we were told about AES trying to buy the 5 acres of land not even 50 feet from us to put this substation. The lack of communication on the City of Piqua's part about this project is more than upsetting and extremely concerning. We were told on the phone that letters were mailed out to the residents in the surrounding area, but when speaking to over 10 neighbors in the surrounding area not one person had received this letter. As residents that live not even 50 feet away from where this building is going to be developed, we should be the first to know what's happening in our backyard.

One of our biggest concerns about this building being built in this location is the health risks that our family and many other families will be facing daily. Electro Magnetic Frequencies (EMF) will be emitted from the AES substations that could cause serious harm to our bodies. Studies on the effects of EMF exposure have linked them to the cause of an increase of white blood cells, decrease in red blood cells, rising blood pressure levels, higher risk of cancer,

Alzheimer's disease, Specific types of heart disease, Nervous system disorder, Immune system disorder, childhood and adult Leukemia, and that's just the beginning of the list. (These studies will be linked on the last page). In addition to the EMF radiation, we would also be losing total darkness due to the industrial light pollution. There are documented studies proving the health risks associated with industrial lighting interrupting the circadian cycle. Evidence suggests that if the circadian rhythm is disrupted it can cause obesity, diabetes, immune deficiencies, and cardiac arrhythmias. We are also extremely concerned about the constant humming that would come off this substation. There are multiple studies proving that exposure to continuous low-frequency noise can cause cardiovascular disease, irritation, distraction, headaches, sleep disruption, increased stress levels, and psychological disorders. With our children being home schooled, they are home most of the day, every day. Exposing them to EMF damage, industrial light pollution, and the continuous low frequency noise every day, all day long would be extremely detrimental to their health. I refuse to stand idly by and let our kids be at risk of a terminal illness in the name of "progress." As a parent, our biggest concern is protecting our children and putting their safety first. The negative consequences that our children, adults, and wildlife, would face from the EMF exposure, industrial light pollution, and the continuous low frequency noise far outweighs any economic benefits to AES.

Our peaceful piece of property that we purchased would forever be changed in a negative way if these substations are allowed to be built. The negative impact is not only health related but the substations would also decrease the property value of our home and homes in the surrounding area from anywhere between 10 to 30 percent. Not only will it be a huge eye sore, but the noise and light pollution itself will deter people away from buying property around here. The light and noise pollution is not only just a nuisance, but also proposes plenty of health risks as well. With that being said, I ask you, how is it justified or fair that you ask us to give all of this up?

It is important to us to preserve as much of our natural surroundings and wildlife as possible. EMFs would affect wildlife, and there is plenty of it out here. It could cause them to become sick, throw off their mating cycle, and cause behavioral issues. The building itself will be intruding on their habitat and cause displacement of several species of birds including the Henslow Sparrow and Northern Harrier, which are endangered, deer, turkeys, coyotes, rabbits,

and even a nesting pair of Bald eagles. We bought our house with the intention of being in a rural area surrounded by wildlife. We have had the pleasure of watching these Bald Eagles teach their fledgling how to fly using the wildflower patch, which would be destroyed by the substation. The rural feeling of our home that we love will be stripped away from us the moment they start breaking ground.

What is the reasoning behind choosing this location for these two substations? Why could these substations not be placed in an undeveloped place nearby? There is land further down on Rt 66 that would have plenty of space for AES to put the substation without affecting any homes and residents. Why should we accept putting our health and safety at risk for the sake of furthering utility development? Why should my family and the families that live in this area have to face the consequences of our property value decreasing? There is no way that my family and I could continue to live in our home if these substations are to be built, and to us, it is unfair that we would have to leave our home that we purchased to live in forever for the sake of “progress.”

Thank you for your time,

Nicholas Brown

<https://pmc.ncbi.nlm.nih.gov/articles/PMC2627884/> - Missing the Dark: Health Effects of Light Pollution

<https://pmc.ncbi.nlm.nih.gov/articles/PMC6025786/> - Effects of EMF exposure on the antioxidant defense system

<https://pmc.ncbi.nlm.nih.gov/articles/PMC9759772/> - The effect of Electrical Fields from High Voltage Transmission Line on Cognitive, Biological, and Anatomical Changes

[Electric and Magnetic Fields from Power Lines | US EPA](#)

[How to Maintain the Electrical Substation Safety Distance from Living Place? | Voltage Lab](#)

[Adverse Health Effects of Nighttime Lighting - American Journal of Preventive Medicine](#)

[Irjet-v2i379.pdf](#) – Effect of High Voltage Transmission Lines on Human Health, Plant, Life, & Animal Activity

[Effects of electromagnetic fields exposure on the antioxidant defense system](#)

<https://pmc.ncbi.nlm.nih.gov/articles/PMC6122264/> - Impacts of Low Frequency Noise Exposure on Well Being

<https://puc.sd.gov/commission/dockets/electric/2013/EL13-028/guidelines.pdf> - Property Value

The **Bald and Golden Eagle Protection Act** (16 [U.S.C.](#) 668-668d) is a [United States federal statute](#) that protects two species of [eagle](#). The [bald eagle](#) was chosen as a national emblem of the [United States](#) by the [Continental Congress](#) of 1782 and was given legal protection by the Bald Eagle Protection Act of 1940. This act was expanded to include the [golden eagle](#) in 1962.^[1] Since the original Act, the Bald and Golden Eagle Protection Act has been amended several times. It currently prohibits anyone, without a [permit](#) issued by the [Secretary of the Interior](#), from "taking" [bald eagles](#). Taking is described to include their parts, nests, or eggs, molesting or disturbing the birds. The Act provides criminal penalties for persons who "take, possess, sell, purchase, barter, offer to sell, purchase or barter, transport, export or import, at any

time or any manner, any bald eagle ... [or any golden eagle], alive or dead, or any part, nest, or egg thereof."^[2]

The purpose of the Bald and Golden Eagle Protection act is to not agitate the bald and golden eagle to the extent of not 1.) Abusing an eagle, 2.) Interfering with its substantial lifestyle, including shelter, breeding, feeding, or 3.) Nest abandonment.^[3] The eagle feathers have been collected and incorporated into clothing, art, jewelry, etc. In addition, having the possession, exchange, or sale of bald eagle feathers violates the act if no permit is obtained. The basic structure of the act resembles the [Migratory Bird Treaty Act](#).

The **Endangered Species Act of 1973** (ESA or "The Act"; 16 U.S.C. § 1531 [et seq.](#)) is the primary law in the United States for protecting and conserving imperiled species. Designed to protect critically imperiled species from [extinction](#) as a "consequence of economic growth and development untempered by adequate concern and conservation", the ESA was signed into law by President [Richard Nixon](#) on December 28, 1973. The [Supreme Court of the United States](#) described it as "the most comprehensive legislation for the preservation of endangered species enacted by any nation".^[1] The purposes of the ESA are two-fold: to prevent extinction and to recover species to the point where the law's protections are not needed. It therefore "protect[s] species and the ecosystems upon which they depend" through different mechanisms. For example, section 4 requires the agencies overseeing the Act to designate imperiled species as threatened or endangered. Section 9 prohibits unlawful 'take,' of such species, which means to "harass, harm, hunt..." Section 7 directs federal agencies to use their authorities to help conserve listed species.^[2] The Act also serves as the enacting legislation to carry out the provisions outlined in The [Convention on International Trade in Endangered Species of Wild Fauna and Flora](#) (CITES).^[3]



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Adverse Health Effects of Nighttime Lighting

Comments on American Medical Association Policy Statement

Richard G. Stevens, PhD ^a · George C. Brainard, PhD ^b · David E. Blask, PhD, MD ^c · Steven W. Lockley, PhD ^d · Mario E. Motta, MD ^e

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Abstract

Abstract

The American Medical Association House of Delegates in June of 2012 adopted a policy statement on nighttime lighting and human health. This major policy statement summarizes the scientific evidence that nighttime electric light can disrupt circadian rhythms in humans and documents the rapidly advancing understanding from basic science of how disruption of circadian rhythmicity affects aspects of physiology with direct links to human health, such as cell cycle regulation, DNA damage response, and metabolism. The human evidence is also accumulating, with the strongest epidemiologic support for a link of circadian disruption from light at night to breast cancer. There are practical implications of the basic and epidemiologic science in the form of advancing lighting technologies that better accommodate human circadian rhythmicity.

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References

1. Council on Science and Public Health Report 4. Light pollution: adverse health effects of nighttime lighting. American Medical Association House of Delegates Annual Meeting. June 2012, Chicago IL.
[Google Scholar](#)
2. Brainard, G.C. · Hanifin, J.P. · Greeson, J.M. ...
Action spectrum for melatonin regulation in humans: evidence for a novel circadian photoreceptor
J Neurosci. 2001; **21**:6405-6412
[PubMed](#) [Google Scholar](#)
3. Takahashi, J.S. · Hong, H.K. · Ko, C.H. ...
The genetics of mammalian circadian order and disorder: implications for physiology and disease
Nat Rev Genet. 2008; **9**:764-775
[Crossref](#) [Scopus \(1291\)](#) [PubMed](#) [Google Scholar](#)
4. Bellet, M.M. · Sassone-Corsi, P.
Mammalian circadian clock and metabolism—the epigenetic link
J Cell Sci. 2010; **123**:3837-3848
[Crossref](#) [Scopus \(180\)](#) [PubMed](#) [Google Scholar](#)
5. Sancar, A. · Lindsey-Boltz, L.A. · Kang, T.H. ...
Circadian clock control of the cellular response to DNA damage
FEBS Lett. 2010; **584**:2618-2625

6. Ota, T. · Fustin, J.M. · Yamada, H. ...
Circadian clock signals in the adrenal cortex
Mol Cell Endocrinol. 2012; **349**:30-37
[Crossref](#) [Scopus \(38\)](#) [PubMed](#) [Google Scholar](#)
7. Hunt, T. · Sassone-Corsi, P.
Riding tandem: circadian clocks and the cell cycle
Cell. 2007; **129**:461-464
[Full Text](#)  [Full Text \(PDF\)](#) [Scopus \(182\)](#) [PubMed](#) [Google Scholar](#)
8. Lewy, A.J. · Wehr, T.A. · Goodwin, F.K. ...
Light suppresses melatonin secretion in humans
Science. 1980; **210**:1267-1269
[Crossref](#) [Scopus \(1542\)](#) [PubMed](#) [Google Scholar](#)
9. Blask, D.E.
Melatonin, sleep disturbance and cancer risk
Sleep Med Rev. 2009; **13**:257-264
[Full Text](#)  [Full Text \(PDF\)](#) [Scopus \(353\)](#) [PubMed](#) [Google Scholar](#)
10. Brainard, G.C. · Hanifin, J.P.
Photons, clocks, and consciousness
J Biol Rhythms. 2005; **20**:314-325
[Crossref](#) [Scopus \(145\)](#) [PubMed](#) [Google Scholar](#)
11. Provencio, I.
The hidden organ in your eyes
Sci Am. 2011; **304**:54-59
[Crossref](#) [Scopus \(12\)](#) [PubMed](#) [Google Scholar](#)
12. Gooley, J.J. · Chamberlain, K. · Smith, K.A. ...
Exposure to room light before bedtime suppresses melatonin onset and shortens melatonin duration in humans
J Clin Endocrinol Metab. 2011; **96**:E463-E472
[Crossref](#) [Scopus \(368\)](#) [PubMed](#) [Google Scholar](#)
13. Cajochen, C. · Frey, S. · Anders, D. ...
Evening exposure to a light-emitting diodes (LED)-backlit computer screen affects circadian physiology and cognitive performance
J Appl Physiol. 2011; **110**:1432-1438
[Crossref](#) [Scopus \(473\)](#) [PubMed](#) [Google Scholar](#)
14. Cappuccio, F.P. · Miller, M.A. · Lockley, S.W.
Sleep, health and society: from aetiology to public health
Oxford University Press, Oxford, UK, 2010
[Crossref](#) [Scopus \(31\)](#) [Google Scholar](#)
15. Wehr, T.A.
In short photoperiods, human sleep is biphasic
J Sleep Res. 1992; **1**:103-107
[Crossref](#) [Scopus \(101\)](#) [PubMed](#) [Google Scholar](#)
16. Stevens, R.G.
Light at night, circadian disruption, and breast cancer: assessment of existing evidence
Int J Epidemiol. 2009; **38**:963-970
[Crossref](#) [Scopus \(274\)](#) [PubMed](#) [Google Scholar](#)
17. Stevens RG, Blask DE, Brainard GC, et al. Meeting Report: The role of environmental lighting and circadian disruption in cancer and other diseases. *Environ Health Perspect* 2007;115:1357–62
[Google Scholar](#)
18. Kamdar, B.B. · Needham, D.M. · Collop, N.A.
Sleep deprivation in critical illness: its role in physical and psychological recovery
J Intensive Care Med. 2012; **27**:97-111

Crossref

Scopus (322)

PubMed

Google Scholar

19.

Blask, D.E. · Brainard, G.C. · Dauchy, R.T. ...

Melatonin-depleted blood from premenopausal women exposed to light at night stimulates growth of human breast cancer xenografts in nude rats

Cancer Res. 2005; 65:11174-11184

Crossref

Scopus (356)

PubMed

Google Scholar

20.

Zhu, Y. · Brown, H.N. · Zhang, Y. ...

Period3 structural variation: a circadian biomarker associated with breast cancer in young women

Cancer Epidemiol Biomarkers Prev. 2005; 14:268-270

PubMed

Google Scholar

21.

Zhu, Y. · Stevens, R.G. · Hoffman, A.E. ...

Epigenetic impact of long-term shiftwork: pilot evidence from circadian genes and whole-genome methylation analysis

Chronobiol Int. 2011; 28:852-861

Crossref

Scopus (127)

PubMed

Google Scholar

22.

Straif, K. · Baan, R. · Grosse, Y. ...

Carcinogenicity of shift-work, painting, and fire-fighting

Lancet Oncol. 2007; 8:1065-1066

Full Text

 Full Text (PDF)

PubMed

Google Scholar

23.

Jia, Y. · Lu, Y. · Wu, K. ...

Does night work increase the risk of breast cancer? A systematic review and meta-analysis of epidemiological studies

Cancer Epidemiol. 2013; 37:197-206

Full Text

 Full Text (PDF)

Scopus (135)

PubMed

Google Scholar

24.

Bambra, C.L. · Whitehead, M.M. · Sowden, A.J. ...

Shifting schedules: the health effects of reorganizing shift work

Am J Prev Med. 2008; 34:427-434

Full Text

 Full Text (PDF)

Scopus (109)

PubMed

Google Scholar

25.

Stevens, R.G.

Does electric light stimulate cancer development in children?

Cancer Epidemiol Biomarkers Prev. 2012; 21:701-704

Crossref

Scopus (7)

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Research Paper



The Effect of Electrical Fields From High-voltage Transmission Line on Cognitive, Biological, and Anatomical Changes in Male Rhesus macaque Monkeys Using MRI: A Case Report Study

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ABSTRACT

Introduction: Living near high-voltage power lines and exposure to high-frequency electromagnetic fields (EMFs) is a potentially serious hazard to animal and human health. The present study was conducted to evaluate the effect of high-frequency EMFs from simulated high-voltage electric towers on cognitive, anatomical, and biological changes in the male macaque.

Methods: In this study, two Rhesus macaque were recruited, one experimental and one control. The experimental subject was exposed to EMFs from 3 kV/m simulated electric towers with a specific protocol and the control subject was tested without irradiation (4h per day, for 30 days). All required tests were performed before and after the intervention on experimental and control monkeys. The anatomical alternation of the prefrontal area (PFA) was measured by MRI images. All tests were performed on irradiated and control animals before and after the intervention and the results were compared between irradiated and control animals.

Results: The results of the present study indicated increased white blood cell counts after high-frequency EMFs irradiation. Also, the red blood cell counts showed a decreasing trend after irradiation. The plasma adrenaline level increased after irradiation. Besides, the blood glucose levels increased after irradiation. The PFA was different before and after the irradiation. Moreover, some behavioral disorders, such as fatigue, drowsiness, anorexia, and insomnia were observed after irradiation.

Conclusion: The results of biological tests and MRI showed an elevated risk of immunodeficiency disorders, weakness, and behavioral disorders. People who live or work near high-voltage electric towers with high-frequency EMFs are warned.

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Highlights

- Magnetic, and electric fields from high pressure towers caused negative effects in terms of biology and even anatomical changes in the prefrontal part of the brain.
- Disturbance in the prefrontal part of the brain caused the monkey's cognitive and behavioral disorder.
- An increase in white blood cells, a decrease in red blood cells, and an increase in the adrenaline and blood sugar were indicative of biological disorders after wave exposure in male rhesus monkeys.
- The effects of magnetic and electric fields resulting from high pressure towers on the nerves and psyche require health researchers to do more studies.

Plain Language Summary

Today, one of the factors that threaten the cognitive and behavioral health of humans and animals is living in the vicinity of magnetic and electric fields resulting from the power transmission of high-pressure towers. These fields cause cognitive and behavioral disorders in living beings. Therefore, because it threatens the cognitive health of creatures, it needs more research.

1. Introduction

Nowadays, exposure to high-frequency electromagnetic fields (EMFs) is a potentially serious hazard to animal and human health (Hamed Aliyari, Hedayat Sahraei, Mohammad Reza Daliri, Beh Minaei-Bidgoli, et al., 2018; LaBar & Cabeza, 2006). According to the literature, people exposed to EMFs are more likely to develop any type of blood cancer, abortion due to poor fetal implantation, and neurological disorders, such as stress, depression, and insomnia due to degradation in neuronal function and dysfunction by reactive oxygen species (ROS) molecule (Bayr, 2005; Garip & Akan, 2010). The ROS may harm the function of hippocampus neurons and is a major contributor to mental illnesses, such as Alzheimer's disease (Aliyari, Hosseinian, Sahraei, & Menhaj, 2018; Harach et al., 2015; Sobel & Davanipour, 1996). Electric fields and currents exist in the body of all living organisms acting as a contributor to physiological control mechanisms, such as the nervous system, cell death, growth, tissue growth, and repair (Cook, Thomas, & Prato, 2002; Paz-Caballero, Cuetos, & Dobarro, 2006). The EMFs are associated with many symptoms, such as dizziness, tinnitus, weakness and fatigue, blurred vision, and drowsiness during work, as well as the emergence of unknown diseases, altered blood composition, impaired musculoskeletal system, and immune system dysfunction among animals and humans (Kazemi et al., 2018a; McGaugh & Roozendaal, 2002; Orban et al., 2003; Elaheh Tekieh et al., 2017). Impaired secretion of hormones may lead to behavioral and cognitive disorders (Hamed

Aliyari, Hedayat Sahraei, Mohammad Reza Daliri, Beh Minaei-Bidgoli, et al., 2018). Accordingly, EMFs adversely affect the secretion of protein and amine hormones by activating G-protein coupled receptors and membrane enzymes (Kazemi et al., 2018; Elaheh Tekieh et al., 2017). The adrenocorticotrophic hormone (ACTH) secreted from the anterior pituitary, acts to stimulate the adrenal cortex hormones and regulates the secretion of cortisol and adrenaline (Fereidouni, Vahidi, Shisheghar, Mehr, & Tahmasbi, 2014; Kazemi et al., 2018). The results of many studies indicate the themes of simulated high voltage towers, the reduction of melatonin secretion resulting in sleep, attention, learning, and memory disturbances, and the development of mental illness, such as depression in Rhesus monkey (H Aliyari et al., 2018; Aliyari, Hosseinian, Menhaj, & Sahraei, 2018; Aliyari et al., 2015; Aliyari, Sahraei, Daliri, Beh Minaei-Bidgoli, et al., 2018; Aliyari, Sahraei, Erfani, Mohammadi, Kazemi, Daliri, Minaei-Bidgol, et al., 2020; Aliyari, Sahraei, Golabi, et al.; Aliyaria et al., 2019; Brady, Konkle, & Alvarez, 2011; Fereidouni et al., 2014; Kazemi et al., 2018, 2018b; Elaheh Tekieh et al., 2017).

Increased secretion of adrenaline increases glucose release from the liver leading to increased blood glucose levels. Thus, the required energy for muscle and nerves is supplied (Aliyari et al., 2015; Brady et al., 2011; Harach, 2010; Elaheh Tekieh et al., 2017). Secretion of adrenaline increases due to stress and abnormal conditions. Producing more adrenaline, in turn, helps increase the amount of energy to adapt to new conditions. Besides, further production of adrenalin may deplete sugar supplies (De Pittà, Volman, Berry, & Ben-Jacob, 2011; Hickie &

Rogers, 2011). In response to environmental factors in stress conditions, the production of T-cell lymphocytes increases (R. Liburdy, Sloma, Sokolic, & Yaswen, 1993; Liburdy, 1992; Poesz et al., 1980). The number of lymphocytes is 70% in apes and 30% in human blood. Environmental factors and stressors can increase white blood cells (WBC) or leukocytes. The abnormal increase in WBC counts may cause immune deficiency, cognitive impairment, infectious diseases, bone marrow failure, and leukemia (Monti et al., 1991). Several studies have shown that the EMFs generated from the simulated high voltage towers reduce the area of the hippocampus and the amygdala in Rhesus monkeys (Duan et al., 2014; Elahe Tekieh et al., 2018). Therefore, this study aimed to investigate the effect of high-frequency EMFs from simulated high-voltage electric towers on cognitive, anatomical, biological, biochemical, and hormonal changes in male Rhesus macaque monkeys.

2. Materials and Methods

Animals

Two Rhesus monkeys (*Macaca mulatta*) aged 4-5 years with an average weight of 4 kg were recruited. All ethical standards regarding animal confinement, transport, location, and maintenance were observed under the international laws and regulations (IR.BUMS.REC.1394.112).

Experimentation protocol and simulation of high-frequency electromagnetic fields (EMFs)

First, pretests were conducted on study subjects. Of the two selected monkeys, one subject was irradiated by 3 kV/m high-voltage EMF, 4h per day for 30 days (Aliyari, Hosseinian, Sahraei, & Menhaj, 2019; Kazemi et al., 2018, 2018b), and one subject was maintained in a non-irradiated environment and tested without irradiation (Aliyari, Hosseinian, Sahraei, & Menhaj, 2019; Kazemi et al., 2018, 2018b). The monkeys were kept in Teflon cages which, in addition to having special conditions for keeping the animal, such as strength, portability, and washability, had special properties to conduct scientific experiments (with the highest transfer properties and lowest resistance) (H. Aliyari et al., 2019; Kazemi et al., 2018). High voltage EMF (3 kV/m) was produced and simulated by a team of experts at Amir Kabir University, Tehran City, Iran. Two metal plates (2×2m) were placed in the upper part and one in the lower part of the cage at a 2 m distance, and a 6 kV EMF was released to produce a uniform EMF of 3 kV inside the cage (1×1×1m) (H Aliyari et al., 2018; Kazemi et al., 2018a; Tekieh et al., 2017).

Behavioral tests

In this study, the monkeys were vaccinated against tetanus, pertussis, diphtheria, and polio before entering the laboratory. After entering the laboratory, it took three months to adapt to the environment and adapt to the researchers. After this period, two perfectly healthy monkeys were included in the study. The monkey that was subjected to high-pressure surges was the freshest, smartest, and most active monkey in the laboratory. For this purpose, all observable behavior in subjects, such as sleeping patterns, sedentary and natural appetite, drowsiness, and depression were observed and recorded before, during, and after intervention by video cameras (Hamed Aliyari, 2018; Aliyari, Sahraei, Erfani, et al.; Aliyari, Sahraei, Erfani, Mohammadi, Kazemi, Daliri, Minaei-Bidgoli, et al., 2020; Aliyaria et al., 2019).

Biological test

Biological tests were performed on the irradiated and control subjects before and after the intervention and during the recovery period, and the obtained data were analyzed. According to the experimental protocol, a fasting period of 15h was required for the monkeys. For biological analysis, a total of 10 cc of blood was taken in three stages of pre-, post-irradiated, and recovery from the femoral artery of the animals, of which 5 cc was used to evaluate changes in adrenaline levels using the primate custom positive selection kit (MyBioSource, USA) at three stages. Another 5 cc of blood samples were used to measure fasting blood sugar, WBC counts, and red blood cell (RBC) count in three stages (H Aliyari, 2018; Hamed Aliyari, Seyed Hossein Hosseinian, et al., 2018; Hamed Aliyari, Hedayat Sahraei, Mohammad Reza Daliri, 2018; Kazemi et al., 2018a; Elahe Tekieh et al., 2018).

The anatomical alternation of the profunda femoris artery (PFA) was measured by MRI images and digital imaging and communications in medicine (DICOM) LiteBox files before and after the intervention (Hamed Aliyari, 2018; Servien, Viskontas, Giuffre, Coolican, & Parker, 2008).

Recovery phase

Both two selected monkeys, one subject exposed to irradiation and one subject maintained in a non-irradiated environment, stayed in the same previous place and situation but both were without irradiation for up to one month (H Aliyari et al., 2019).

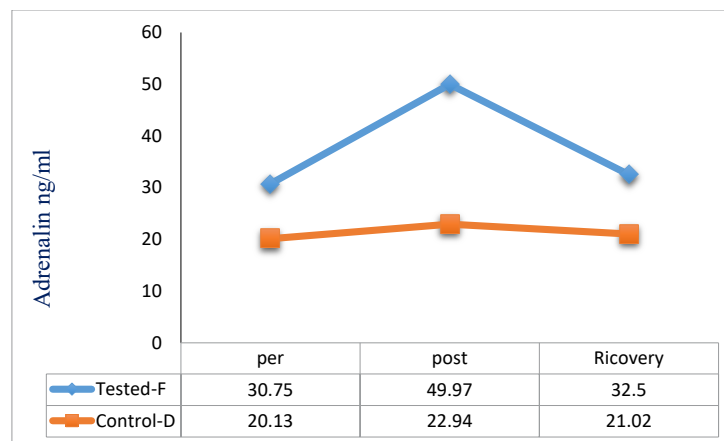


Figure 1. Adrenaline plasma levels (pre-test, post-test, recovery)

NEURSCIENCE

The serum adrenaline levels were shown to elevate after irradiation. The adrenaline levels during the recovery phase declined to the pre-irradiation phase.

3. Results

The behavioral results of the study showed that in the tested monkey exposed to the electric field of the simulated high-pressure rig, the behavioral-cognitive indices change over time. From the first day to the 30th day of the waving, cognitive changes were visible to the naked eye (recording behavior by camcorders). Our observations of monkeys under a high-pressure electric field showed states of impatience, lethargy, anorexia, sleep disturbance, inactivity, and state of depression.

Behavioral tests investigated observable cognitive changes in the study subjects, including drowsiness, loss of appetite, sleep deprivation, fatigue, inactivity, and depression (recorded by video cameras). Behavioral results showed an increasing trend in the men-

tioned criteria during thirty days of irradiation. The behavioral analysis was performed one month before, during, and after irradiation (recovery phase). Behavioral tests were also performed on the control animal at three stages without irradiation, and no difference was observed in the control monkey.

The serum adrenaline levels were shown to elevate after high-frequency EMFs irradiation compared to the control monkeys. In addition, the adrenaline levels declined during the recovery phase to the pre-irradiation phase. No difference was observed in the three phases in the control monkeys (Figure 1).

The fast blood glucose levels were shown to increase after high-frequency EMFs irradiation compared to the control monkeys. Also, the blood glucose levels declined

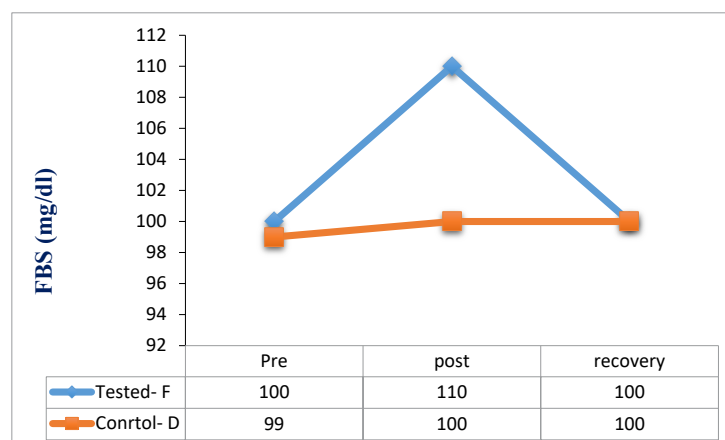


Figure 2. Fast blood sugar levels (pre-test, post-test, recovery)

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The increasing trend of fast blood glucose levels after irradiation. The fast blood glucose levels during the recovery phase were declining to the pre-irradiation phase

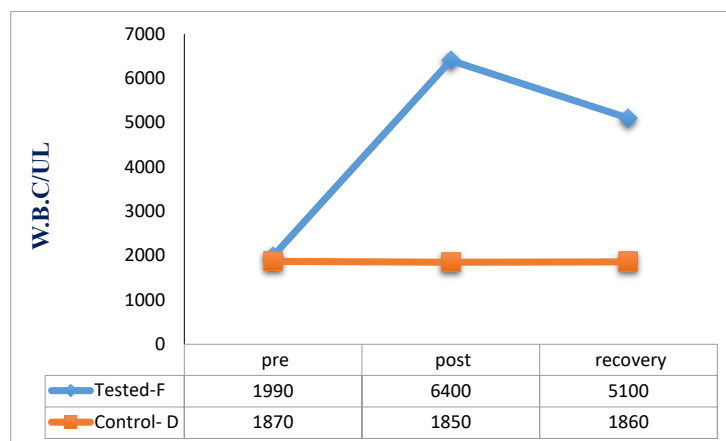


Figure 3. White Blood Cells (WBC) counts (pre-test, post-test, recovery)

NEURSCIENCE

The increasing trend of WBC counts after irradiation. The WBC counts during the recovery phase declined to the pre-irradiation phase.

during the recovery phase to the pre-irradiation phase. No difference was observed in the three phases in the control monkeys (Figure 2).

The WBC counts showed an increasing trend after high-frequency EMF irradiation compared to the control monkey (Figure 3).

The RBC counts were shown to decrease after high-frequency EMFs irradiation compared to the control monkeys. Besides, the RBC counts increased during the recovery phase to the pre-irradiation phase. No difference was observed in the three phases in the control monkeys (Figure 4).

The PFA decreased after irradiation in the experimental monkey compared to the control monkeys. Also, the PFA during the recovery phase increased to the pre-irradiation phase.

diation phase. No anatomical difference was observed in the control monkey (Figures 5).

4. Discussion

Today, industrialization has remade a major part of people's life. Rapidly growing industrialized cities increase the growth of power lines and the proximity of overhead electric towers to residential and occupational places increases the risk of EMFs harm as a global public concern. According to the literature, the EMFs generated by high-pressure electric towers are a serious threat to the environment of animals and humans. This destructive environmental factor adversely affects health and lifestyle and causes cognitive and behavioral changes in animals and humans (Aliyari et al., 2015; Hamed Aliyari, Hedayat Sahraei, Mohammad Reza Daliri, Beh Minaei-Bidgoli, et al., 2018; Kazemi et al., 2018; Liburdy et al., 1993; Monti et al., 1991).

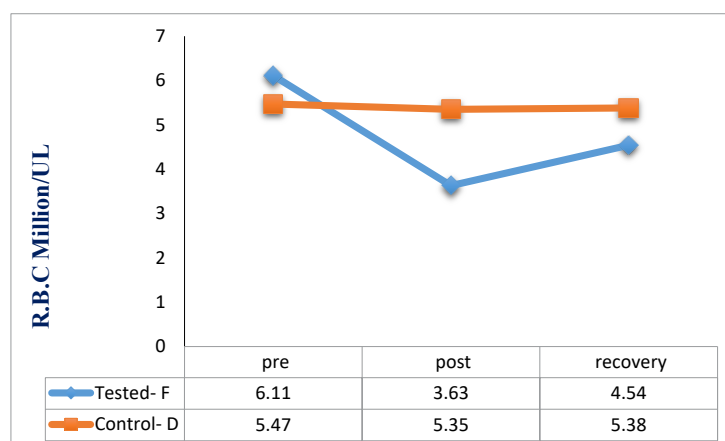


Figure 4. Red Blood Cell (RBC) counts (pre-test, post-test, recovery)

NEURSCIENCE

The RBC counts were shown to decrease after irradiation. The RBC counts during the recovery phase elevated to the pre-irradiation phase.

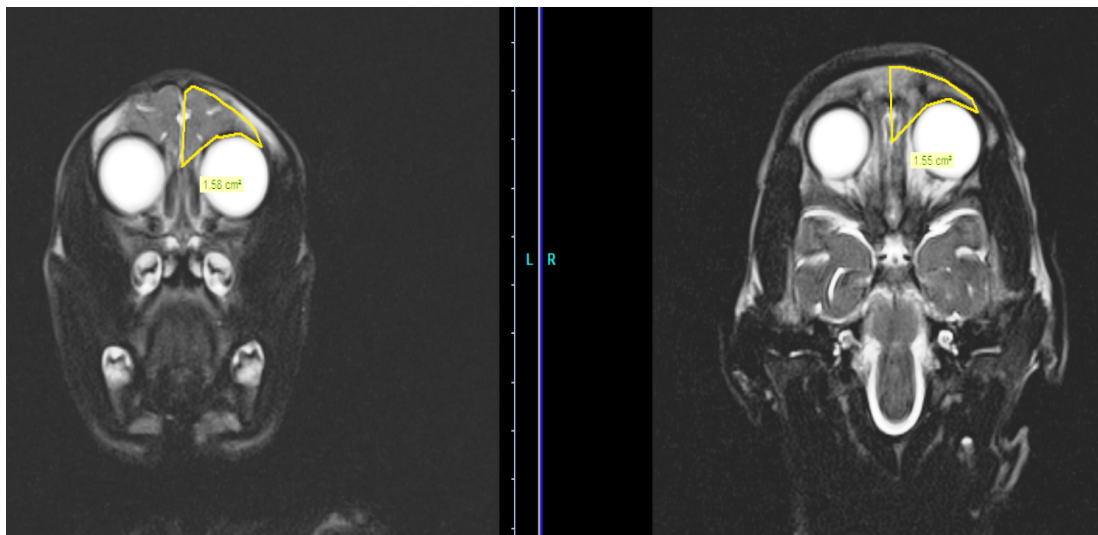


Figure 5. Pre-frontal Area (PFA)

NEURSCIENCE

The pre-frontal area was shown to decrease after irradiation. The pre-frontal area during the recovery phase elevated to the pre-irradiation phase

Based on our results, the cognitive and behavioral elements were different after exposure to EMFs from simulated high-pressure towers in the irradiated subjects. Behavioral analysis of experimental and control monkeys revealed that homogeneous behavioral indices, such as refreshment, sedentary, and natural appetite were observed in control monkeys, whereas experimental monkeys showed drowsiness, loss of appetite, sleep deprivation, fatigue, and depression after EMFs irradiation. These behavioral and cognitive changes in the tested monkey showed an increasing trend from the first day to the last day of the waving. On the other hand, from day 30 onwards, with the interruption of the waving, cognitive and behavioral changes returned to the initial state before the waving. It indicates the reversible effects of the fields caused by high-pressure rigs. According to research, people who live near high-pressure towers develop cognitive impairments (Aliyari, Hosseini, Menhaj, & Sahraei, 2019). The results of this study showed that exposure to high-frequency EMFs reduced melatonin secretion leading to sleep deprivation and immune deficiency in male Rhesus monkeys. sleep deprivation and immune deficiency are major contributors to depression (Burke, Davis, Otte, & Mohr, 2005; Hickie & Rogers, 2011; Thibodeau, Jorgensen, & Kim, 2006). Besides, high-frequency EMFs have been shown to reduce gene expression of the NMDA receptor and subsequently reduce plasma sodium and potassium levels. Sodium and potassium are the most important biological ions that cause irritability of the neurons and transmissions of nerve impulses. It is fundamental to note that sodium, potassium, and the NMDA receptor gene

are crucial elements in learning and memory processes (Basar, 2016; Clark & Mayer, 2016; De Zeeuw & Ten Brinke, 2015; Devesa, Lema, et al., 2016; Gruart, Leal-Campanario, López-Ramos, & Delgado-García, 2015). Exposure to extremely low-frequency EMFs (ELF-EMF 12Hz) has been shown to increase melatonin secretion. The metallothionein-1 (MT1) (or Mel1A) and metallothionein-2 (MT2) (or Mel1B) are two major receptors of melatonin which are protein-coupled receptors (GPCR). When receptors of melatonin bind to melatonin, the protein kinase A (PKA) or Protein kinase C (PKC) enzymes are activated (Kazemi et al., 2018a; Elahe Tekieh et al., 2018). Also, ELF-EMFs at a frequency of 12 Hz increase gene expression of N-methyl D-aspartate (NMDA), and subsequently improve visual memory of male Rhesus monkeys. The ELF EMFs stimulate glutamate on NMDA receptors and inhibits magnesium from the NMDA membrane receptor, resulting in more sodium outside and more potassium inside the cell (Kazemi et al., 2018a; Lau & Zukin, 2007; Salunke, Umathe, & Chavan, 2014). The highest density of the NMDA receptor gene is found in the hippocampus, amygdala, and prefrontal cortex in the central nervous system which plays a vital role in learning and memory processes (H Aliyari et al., 2018; Aliyari et al., 2015; Hamed Aliyari, Hedayat Sahraei, Mohammad Reza Daliri, Beh Minaei-Bidgoli, et al., 2018; Basar, 2016; Devesa, Lema, et al., 2016; Elahe Tekieh et al., 2018).

The findings of the current study also reveal that the plasma concentration of adrenaline increased after high-frequency EMF irradiation in the experimental monkeys. Adrenaline is a catecholamine secreted from the

central part of the adrenal gland, and when cortisol levels are low, adrenaline is secreted in response to anxiety and helps to chill and cope with tragedies. Increased adrenaline levels among study subjects may be due to impaired behaviors in this study. The activity of the adrenaline hormone is dependent on protein-coupled receptors (GPCR), and the activity of adenylate cyclase and increased cyclic adenosine monophosphate (cAMP) as a secondary messenger activates adrenaline (McGaugh & Roozendaal, 2002; Miao, Jänig, & Levine, 2000).

Hormones are chemicals released to develop and enhance cognitive capabilities, and any stimulus, environmental factor, or behavioral and cognitive impairments influence their secretion. Evidence shows that stress coping strategies in male Rhesus monkeys are different, and the cortisol and adrenaline secretion varies depending on the personal characteristics of the animals (Aliyari et al., 2015; Devesa, Almengló, & Devesa, 2016; Tekieh et al., 2017). Biochemical studies have shown that blood glucose increased after exposure to simulated high-frequency EMFs. Adrenaline (epinephrine) is shown to elevate blood glucose which is consistent with the findings of this study. Moreover, results from hematological studies indicated a reduction in RBC counts among irradiated monkeys after exposure to high-frequency EMFs. Reduced RBC counts (anemia) are associated with drowsiness, fatigue, immune deficiency, and depression in irradiated animals, which is consistent with the results of behavioral tests in subjects exposed to high-frequency EMFs radiation.

Previous studies have shown that exposure to high-voltage electric fields is associated with sleep and depression in male Rhesus monkeys (Hamed Aliyari, 2018; Hickie & Rogers, 2011). Results from hematological studies also showed an increase in the WBC counts after irradiation. Increased WBC counts as an infectious agent may impair normal immune function. The results from behavioral tests indicate a weakened immune system, drowsiness, and inactivity amongst subjects exposed to simulated high-frequency EMFs, which can be attributed to the immune deficiency of the male Rhesus monkey.

The anatomical assessment by MRI is a common and non-invasive technique used by neurologists to examine neurological disorders, such as Alzheimer's disease. Cerebral atrophy in MRI of the hippocampus indicates the presence of Alzheimer's disease. According to the results from anthropometric measurements of PFA by MRI via DICOM LiteBox, the irradiated subject showed

a decreasing trend in PFA after the irradiation compared to the control monkeys (Servien et al., 2008).

The frontal lobes are involved in behavior and personality. The smallest anatomical changes in the PFA can rapidly alter behavior and personality and cause behavioral and cognitive impairments. The frontal lobe is the vital part of the brain that plays a major role in cognition and behavior. Disruption in it disrupts natural behaviors and cognitive indicators (Kazemi et al., 2018a). Previous studies have shown that high-frequency EMFs can cause anatomical changes in the hippocampus and amygdale MRI of male Rhesus monkeys (Laakso et al., 1995; Soinen et al., 1994). Kazemi et al. argued that no changes were observed in hippocampus MRI of male Rhesus monkeys after exposure to low-frequency EMFs at a frequency of 12 Hz (Kazemi et al., 2018a).

It is essential to note that the recovery phase is a period in which the subject is recovered to the pre-irradiation level. Although the effect of high-frequency EMFs is temporary, the subject was irradiated 4h a day for four months. Besides, people living near high-voltage power lines are constantly exposed to high-frequency EMFs. Thus, further research is required to precisely examine the various pathological conditions.

5. Conclusion

The findings of the present study showed that the observable behavioral disorders, such as fatigue, anorexia, sleep deprivation, and depression in the experimental subject exposed to the electric field from simulated high-pressure towers were consistent with the results of other tests. The increase in adrenalin concentration increases glucose levels. Increased WBC counts cause immune deficiency. Decreased RBC counts lead to anemia, fatigue, and drowsiness in the experimental monkeys. All matched the monkey's behavior. It can be concluded that the EMFs from high-pressure electric towers are a serious hazard to cognitive abilities and can lead to mental disorders in humans and animals.

Ethical Considerations

Compliance with ethical guidelines

All ethical considerations based on the international standard were observed (IR.BUMS.REC.1394.112).

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Authors' contributions

Conceptualization: Hamed Aliyari, Seyed Hossein Hosseini, and Mohammad Bagher Menhaj; Methodology: Hamed Aliyari, Masoomah Kazemi, Hedayat Sahraei, and Sahar Golabi; Investigation: Masoomah Kazemi, Sahar Golabi, and Hamed Aliyari; Writing-original draft: Masoomah Kazemi, Sahar Golabi, and Hamed Aliyari; Writing-review, and editing: Hedayat Sahraei, Hamed Aliyari, and Sahar Golabi; Resources: Seyed Hossein Hosseini; Supervision: Seyed Hossein Hosseini.

Conflict of interest

The authors declared no conflict of interest.

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Reference

- Aliyari, H., Sahraei, H., Daliri, M. R., Minaei-Bidgoli, B., Kazemi, M., Agaei H, et al. (2018). The beneficial or harmful effects of computer game stress on cognitive functions of players. *Basic and Clinical Neuroscience*, 9(3):177. [DOI:10.29252/nirp.bcn.9.3.177]
- Aliyari, H., Sahraei, H., Erfani, M., Mohammadi, M., Kazemi, M., Daliri, M. R., et al. (2020). Changes in cognitive functions following violent and football video games in young male volunteers by studying brain waves. *BCN*, (3), 279-288. <https://bcn.iums.ac.ir/article-1-1287-en.html>
- Aliyari, H., Sahraei, H., Golabi, S., Kazemi, M., Daliri, M. R., Minaei-Bidgoli, B. (2021). The effect of brain teaser games on the attention of players based on hormonal and brain signals changes. *Basic and Clinical Neuroscience*, 12(5), 587-596. [DOI:10.32598/bcn.2021.724.9]
- Aliyari, H., Kazemi, M., Tekieh, E., Salehi, M., Sahraei, H., & Daliri, MR, et al. (2015). The effects of Fifa 2015 computer games on changes in cognitive, hormonal and brain waves functions of young men volunteers. *Basic and Clinical Neuroscience*, 6(3), 193-201.
- Aliyari, H., Hosseini, S. H., Menhaj, M. B., & Sahraei, H. (2018) Analysis of the effects of high-voltage transmission line on human stress and attention through electroencephalography (EEG). *Iranian Journal of Science and Technology, Transactions of Electrical Engineering*, 2018, 1-8. [DOI:10.1007/s40998-018-0151-8]
- Aliyari, H., Hosseini, S., Sahraei, H., & Menhaj, M. (2019). Effect of proximity to high-voltage fields: Results of the neural network model and experimental model with macaques. *International Journal of Environmental Science and Technology*, 16(8), 4315-4326. [DOI:10.1007/s13762-018-1830-8]
- Aliyari, H., Sahraei, H., Erfanid, M., Tekieh, E., Salehi, M., Kazemi, M., et al. (2019). The impacts of video games on cognitive function and cortisol levels in young female volunteers. *Journal of Experimental and Clinical Neurosciences*, 6(1), 1-5. [DOI:10.13183/jecns.v6i1.87]
- Basar, E. (2016). Memory and brain dynamics: *Oscillations integrating attention, perception, learning, and memory*. CRC press. . [DOI:10.1201/9780203298732]
- Bayr, H. (2005). Reactive oxygen species. *Critical Care Medicine*, 33(12), S498-S501. [DOI:10.1097/01.CCM.0000186787.64500.12]
- Brady, T. F., Konkle, T., & Alvarez, G. A. (2011). A review of visual memory capacity: Beyond individual items and toward structured representations. *Journal of Vision*, 11(5), 4. [DOI:10.1167/11.5.4]
- Burke, H. M., Davis, M. C., Otte, C., & Mohr, D. C. (2005). Depression and cortisol responses to psychological stress: A meta-analysis. *Psychoneuroendocrinology*, 30(9), 846-856. [DOI:10.1016/j.psyneuen.2005.02.010]
- Clark, R. C., & Mayer, R. E. (2016). E-learning and the science of instruction: Proven guidelines for consumers and designers of multimedia learning. John Wiley & Sons. [DOI:10.1002/9781119239086]
- Cook, C., Thomas, A., & Prato, F. (2002). Human electrophysiological and cognitive effects of exposure to ELF magnetic and ELF modulated RF and microwave fields: A review of recent studies. *Bioelectromagnetics*, 23(2), 144-157. [DOI:10.1002/bem.107]
- De Pittà, M., Volman, V., Berry, H., & Ben-Jacob, E. (2011). A tale of two stories: A stroke regulation of synaptic depression and facilitation. *PLoS Computational Biology*, 7(12), e1002293. [DOI:10.1371/journal.pcbi.1002293]
- De Zeeuw, C. I., Ten Brinke, M. M. (2015). Motor learning and the cerebellum. *Cold Spring Harbor Perspectives in Biology*, 7(9), a021683. [DOI:10.1101/cshperspect.a021683]
- Devesa, J., Almengló, C., & Devesa, P. (2016). Multiple effects of growth hormone in the body: Is it really the hormone for growth? *Clinical Medicine Insights. Endocrinology and Diabetes*, 9, 47-71. [DOI:10.4137/CMED.S38201]

- Devesa, J., Lema, H., Zas, E., Munín, B., Taboada, P., & Devesa, P. (2016). Learning and memory recoveries in a young girl treated with growth hormone and neurorehabilitation. *Journal of clinical medicine*, 5(2), 14. [DOI:10.3390/jcm5020014]
- Duan, Y., Wang, Z., Zhang, H., He, Y., Fan, R., Cheng, Y., et al. (2014). Extremely low frequency electromagnetic field exposure causes cognitive impairment associated with alteration of the glutamate level, MAPK pathway activation and decreased CREB phosphorylation in mice hippocampus: Reversal by procyanidins extracted from the lotus seedpod. *Food & Function*, 5(9), 2289-2297. [DOI:10.1039/C4FO00250D]
- Fereidouni, A., Vahidi, B., Shishehgar, F., Mehr, T. H., & Tahmasbi, M. (2014). Human body modeling in the vicinity of high voltage transmission lines. *Science International*, 26(3). [Link]
- Garip, A., Akan, Z. (2010). Effect of ELF-EMF on number of apoptotic cells; correlation with reactive oxygen species and HSP. *Acta Biologica Hungarica*, 61(2), 158-167. [DOI:10.1556/ABiol.61.2010.2.4]
- Gruart, A., Leal-Campanario, R., López-Ramos, JC, & Delgado-García, J. M. (2015). Functional basis of associative learning and its relationships with long-term potentiation evoked in the involved neural circuits: Lessons from studies in behaving mammals. *Neurobiology of Learning and Memory*, 124, 3-18. [DOI:10.1016/j.nlm.2015.04.006]
- Harach, T., Marungruang, N., Dutilleul, N., Cheatham, V., McCoy, K., Neher, J., et al. (2015). Reduction of Alzheimer's disease beta-amyloid pathology in the absence of gut microbiota. arXiv preprint arXiv:150902273. [DOI:10.48550/arXiv.1509.02273]
- Hickie, I. B., & Rogers, N. L. (2011). Novel melatonin-based therapies: Potential advances in the treatment of major depression. *The Lancet*, 378(9791), 621-631. [DOI:10.1016/S0140-6736(11)60095-0]
- Kazemi, M., Sahraei, H., Aliyari, H., Tekieh, E., Saberi, M., Tavakoli, H., et al. (2018). Effect of extremely low frequency electromagnetic fields (ELF/MF) on NMDA-receptor gene expression and visual working memory of male rhesus macaques. *Basic and Clinical Neuroscience*, 9(3), 177-186. [DOI:10.29252/nirp.bcn.9.3.167]
- Laakso, M. P., Soininen, H., Partanen, K., Helkala, E. L., Hartikainen, P., Vainio, P., et al. (1995). Volumes of hippocampus, amygdala and frontal lobes in the MRI-based diagnosis of early Alzheimer's disease: correlation with memory functions. *Journal of Neural Transmission. Parkinson's Disease and Dementia Section*, 9(1), 73-86. [DOI:10.1007/BF02252964]
- LaBar, K. S., & Cabeza, R. (2006). Cognitive neuroscience of emotional memory. *Nature Reviews Neuroscience*, 7(1), 54-64. [DOI:10.1038/nrn1825]
- Lau, C. G., & Zukin, R. S. (2007). NMDA receptor trafficking in synaptic plasticity and neuropsychiatric disorders. *Nature reviews. Neuroscience*, 8(6), 413-426. [DOI:10.1038/nrn2153]
- Liburdy, R., Sloma, T., Sokolic, R., Yaswen, P. (1993). ELF magnetic fields, breast cancer, and melatonin: 60 Hz fields block melatonin's oncostatic action on ER+ breast cancer cell proliferation. *Journal of Pineal Research*, 14(2), 89-97. [DOI:10.1111/j.1600-079X.1993.tb00491.x]
- Liburdy, R. P. (1992). Calcium signaling in lymphocytes and ELF fields evidence for an electric field metric and a site of interaction involving the calcium ion channel. *FEBS Letters*, 301(1), 53-59. [DOI:10.1016/0014-5793(92)80209-Y]
- McGaugh, J. L., & Roozendaal, B. (2002). Role of adrenal stress hormones in forming lasting memories in the brain. *Current Opinion in Neurobiology*, 12(2), 205-210. [DOI:10.1016/S0959-4388(02)00306-9]
- Miao, F. J., Janig, W., & Levine, J. D. (2000). Nociceptive neuroendocrine negative feedback control of neurogenic inflammation activated by capsaicin in the rat paw: Role of the adrenal medulla. *The Journal of Physiology*, 527(Pt 3), 601-610. [DOI:10.1111/j.1469-7793.2000.00601.x]
- Monti, M., Pernecco, L., Moruzzi, M., Battini, R., Zaniol, P., Barbiroli, B. (1991). Effect of ELF pulsed electromagnetic fields on protein kinase C activation process in HL-60 leukemia cells. *Journal of Bioelectricity*, 10(1-2), 119-130. [DOI:10.3109/15368379109031403]
- Murugappan, M., Ramachandran, N., & Sazali, Y. (2010). Classification of human emotion from EEG using discrete wavelet transform. *Journal of Biomedical Science and Engineering*, 3(04):390. [DOI:10.4236/jbise.2010.34054]
- Orban, G. A., Fize, D., Peuskens, H., Denys, K., Nelissen, K., Sanaert, S., et al. (2003). Similarities and differences in motion processing between the human and macaque brain: Evidence from fMRI. *Neuropsychologia*, 41(13), 1757-1768. [DOI:10.1016/S0028-3932(03)00177-5]
- Paz-Caballero, D., Cuertos, F., & Dobarro, A. (2006). Electrophysiological evidence for a natural/artificial dissociation. *Brain Research*, 1067(1), 189-200. [DOI:10.1016/j.brainres.2005.10.046]
- Poiesz, B. J., Ruscetti, F. W., Gazdar, A. F., Bunn, P. A., Minna, J. D., Gallo, R. C. (1980). Detection and isolation of type C retrovirus particles from fresh and cultured lymphocytes of a patient with cutaneous T-cell lymphoma. *Proceedings of the National Academy of Sciences*, 77(12), 7415-7419. [DOI:10.1073/pnas.77.12.7415]
- Salunke, B. P., Umathe, S. N., & Chavan, J. G. (2014). Involvement of NMDA receptor in low-frequency magnetic field-induced anxiety in mice. *Electromagnetic Biology and Medicine*, 33(4), 312-326. [DOI:10.3109/15368378.2013.839453]
- Servien, E., Viskontas, D., Giuffre, B. M., Coolican, M.R., & Parker, D. A. (2008). Reliability of bony landmarks for restoration of the joint line in revision knee arthroplasty. *Knee Surgery, Sports Traumatology, Arthroscopy*, 16(3), 263-269. [DOI:10.1007/s00167-007-0449-y]
- Sobel, E., & Davanipour, Z. (1996). Electromagnetic field exposure may cause increased production of amyloid beta and eventually lead to Alzheimer's disease. *Neurology*, 47(6), 1594-1600. [DOI:10.1212/WNL.47.6.1594]
- Soininen, H. S., Partanen, K., Pitkänen, A., Vainio, P., Hänninen, T., Hallikainen, M., et al. (1994). Volumetric MRI analysis of the amygdala and the hippocampus in subjects with age-associated memory impairment: Correlation to visual and verbal memory. *Neurology*, 44(9), 1660-1668. [DOI:10.1212/WNL.44.9.1660]
- Tekieh E, Riahi E, Kazemi M, Sahraei H, Tavakoli H, Aliyari H, et al. (2017). Role of basal stress hormones and amygdala dimensions in stress coping strategies of male rhesus mon-

keys in response to a hazard-reward conflict. *Iranian Journal of Basic Medical Sciences*, 20(8), 951-957. [DOI:10.22038/IJBMS.2017.9120]

Tekieh, E., Kazemi, M., Tavakoli, H., Saberi, M., Ghanaati, H., Hajinasrollah, M., et al. (2018). The effect of extremely low frequency electromagnetic fields on visual learning & memory and anatomical structures of the brain in male rhesus monkeys. *ISMJ*, 21(1), 40-53. [DOI:10.29252/ismj.21.1.40]

Thibodeau, R., Jorgensen, R. S., & Kim, S. (2006). Depression, anxiety, and resting frontal EEG asymmetry: A meta-analytic review. *Journal of Abnormal Psychology*, 115(4), 715-729. [DOI:10.1037/0021-843X.115.4.715]



Review

Effects of electromagnetic fields exposure on the antioxidant defense system



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ABSTRACT

Technological devices have become essential components of daily life. However, their deleterious effects on the body, particularly on the nervous system, are well known. Electromagnetic fields (EMF) have various chemical effects, including causing deterioration in large molecules in cells and imbalance in ionic equilibrium. Despite being essential for life, oxygen molecules can lead to the generation of hazardous by-products, known as reactive oxygen species (ROS), during biological reactions. These reactive oxygen species can damage cellular components such as proteins, lipids and DNA. Antioxidant defense systems exist in order to keep free radical formation under control and to prevent their harmful effects on the biological system. Free radical formation can take place in various ways, including ultraviolet light, drugs, lipid oxidation, immunological reactions, radiation, stress, smoking, alcohol and biochemical redox reactions. Oxidative stress occurs if the antioxidant defense system is unable to prevent the harmful effects of free radicals. Several studies have reported that exposure to EMF results in oxidative stress in many tissues of the body. Exposure to EMF is known to increase free radical concentrations and traceability and can affect the radical couple recombination. The purpose of this review was to highlight the impact of oxidative stress on antioxidant systems.

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1. Introduction

Electromagnetic fields (EMF) are emitted by many natural and man-made sources that play important roles in daily life. More than 3 billion people across the world are exposed to EMF every day [1]. Lifetime exposure to EMF is becoming the subject of significant scientific investigation since it has the potential to cause crucial changes and deleterious effects in biological systems. The biological impacts of EMF can be classified as thermal and non-thermal. Thermal effects are associated with the heat created by EMFs in a certain area. This mechanism occurs via an alteration in temperature deriving from radiofrequency (RF) fields. It is possible that every interaction between RF fields and living tissues causes an energy transfer resulting in a rise in temperature. The skin and

other superficial tissues usually absorb the non-thermal radiations emitted by mobile phones; this causes the insignificant increase of temperature of the brain or other organs in the body [2]. Nonthermal mechanisms are those that are not directly associated with this temperature change but rather to some other changes in the tissues in association with the amount of energy absorbed [3,4]. Studies on the health effects of RF energy from communication systems have revealed that non-thermal effects should also be discussed. The fact that the possible biophysical mechanisms of RF-EMF interaction with living cells have not yet been fully elucidated is one of the reasons for these discussions [4]. A significant part of many studies concerning EMF have investigated the “non-thermal” effects of RF on biological tissues [5,6]. It has been observed that this effect is mediated by generation of reactive oxygen species (ROS) [7]. ROS are involved in various cellular functions. They can be essential or extremely toxic to cellular homeostasis [8]. Their cytotoxic effects derive from peroxidation of membrane phospholipids. This creates a change in the conductivity of the membrane and loss of membrane integrity [9]. Exposure to EMF has been observed to cause increased free radical production in the cellular environment. Living organisms have anti-oxidative mechanisms, such as glutathione (GSH), glutathione peroxidase (GPx), catalase (CAT), and superoxide dismutase (SOD), in order to alleviate the damage caused by ROS and their products [10]. This defense mechanism acts by sup-

Abbreviations: EMF, electromagnetic fields; RF, radiofrequency; ROS, reactive oxygen species; GSH, glutathione; GPx, glutathione peroxidase; GR, glutathione reductase; GST, glutathione S-transferase; CAT, catalase; SOD, superoxide dismutase; HSP, heat shock protein; EMF/RF, electromagnetic frequency and radiofrequency exposures; ELF-EMFs, exposure to extremely low frequency; MEL, melatonin; FA, folic acid; MDA, malondialdehyde.

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pressing or impairing the chain reaction triggered by ROS. In this case, antioxidant defense mechanisms are impaired by being subjected to an agent that causes overproduction of ROS, including EMF, thus resulting in oxidative stress [11,12]. Studies in recent years have reported that free radicals play a major role in the mechanism behind many diseases, such as diabetes and cancer [13–15]. However, there is still much uncertainty on the subject, and several questions remain to be answered.

This review evaluated the effect of exposure to EMF on biological tissues by concentrating on alterations in several antioxidant enzyme activities and different parameters of oxidation.

2. Electromagnetic field effects

A wide spectrum of electromagnetic waves are today emitted by radar, communication equipment, mobile phone base stations, high voltage lines, radio and television transmitters, substations, and electrical equipment at home and work, in addition to many electrical systems in the environment [16]. The Global System for Mobile Communications (GSM, 850–900 MHz and 1850–1990 MHz) is currently the most extensive system for mobile telecommunications worldwide [17,18]. The mobile phone models (1800 MHz –2200 MHz), laptops (1000 MHz–3600 MHz) and wireless networks in use today function with high frequency (2.45 GHz) microwave radiation [19]. In parallel to technological developments in this century, technological devices are becoming ever more important in daily life. However, despite making life easier, they may also cause a number of health problems. In particular, the average age of beginning mobile phone use has decreased rapidly to elementary school age, and durations of exposure to EMF are also increasing. One study reported that extremely low exposure to EMF from mobile phones may cause health problems [20]. Several studies have reported findings such as stress, headache, tiredness, anxiety, decreased learning potential, impairment in cognitive functions and poor concentration in case of exposure to microwave radiation emitted from mobile phones [2,21,22]. EMFs influence metabolic processes in the human body and exert various biological effects on cells through a range of mechanisms. EMF disrupts the chemical structures of tissue since a high degree electromagnetic energy absorption can change the electric current in the body [23]. As a result of this exposure, the functions of organs are affected. Electric fields exert an oscillatory force on every free ion on the both sides of the plasma membrane and cause them to cross it. This movement of ions causes deterioration in the ion channels on the membrane, biochemical changes in the membrane and consequently impairment of all cellular functions [24].

Exposure to EMFs can damage biological tissues by inducing changes, which can be explained in terms of thermal or non-thermal mechanisms [25]. Thermal effects can occur with the conversion and absorption of heat by the body's electromagnetic energy. Increased body temperature is stabilized and alleviated by blood circulation. Although non-thermal effects do not raise the body temperature sufficiently to impair the structure of tissues, their effects can still be seen as an increase in free radical production in tissues [3]. EMFs, no matter where they occur in the frequency spectrum, are reported to causes a rise in levels of oxygen free radicals in an experimental environment in plants and humans [26].

3. EMF-related oxidative stress and effects on tissue

Free radicals are reactive molecules produced during the conversion of foods into energy through oxygen. The formation of free radicals is an oxidation reaction that occurs on an oxygen basis. [27]. Since oxygen is essential for survival, the formation of free radicals

cannot be avoided. However, factors including ionizing and non-ionizing radiation alter the transcription and translation of genes such as JUN, HSP 70 and MYC, via the epidermal growth factor receptor EGFR-ras, leading to the generation of ROS [28,29] and resulting in the overproduction of ROS in tissues [30].

The Fenton reaction is a catalytic process that converts hydrogen peroxide, a product of mitochondrial oxidative respiration, into a highly toxic hydroxyl free radical. Some studies have suggested that EMF is another mechanism through the Fenton reaction, suggesting that it promotes free radical activity in cells [31,32]. Although some researchers have reported that ROS perform beneficial function, a high degree of ROS production may cause cellular damage, resulting in a range of diseases. These radicals react with various biomolecules, including DNA (Fig. 1). Namely, the energy of free radicals is not enough, and for this reason they behave like robbers who seize energy from other cells and rob a person to satisfy themselves [33]. Many studies have suggested that EMF may trigger the formation of reactive oxygen species in exposed cells in vitro [34–37] and in vivo [7,31,38]. The initial stage of the ROS production in the presence of RF is controlled by the NADPH oxidase enzyme located in the plasma membrane. Consequently, ROS activate matrix metalloproteases, thereby initiating intracellular signaling cascades to warn the nucleus of the presence of external stimulation. These changes in transcription and protein expression are observed after RF exposure [39]. Kazemi et al. investigated the effect of exposure to 900-MHz on the induction of oxidative stress and the level of intracellular ROS in human mononuclear cells. Excessive elevation in ROS levels is an important cause of oxidative damage in lipids and proteins and nucleic acids. It therefore causes changes in enzyme activity and gene expression, eventually leading to various diseases, including sleep disorder, atherosclerosis, loss of appetite, diabetes, dizziness, rheumatoid arthritis, cardiovascular disease, nausea and stroke [40–42]. In addition, degradation of the pro-oxidant-antioxidant balance due to an uncontrolled increase in ROS may also result in lipid peroxidation. Lipid peroxidation is the process in which cell membranes are rapidly destroyed due to the oxidation of components of phospholipids containing unsaturated fatty acids. By continuing this reaction, lipid peroxides (-CO, H) accumulate in the membrane, and transform polyunsaturated fatty acids into biologically active substances [43]. Consequently, lipid peroxidation leads to significant damage in the cells, such as disturbances in membrane transport, structural changes, cell membrane fluidity, damage to protein receptors in membrane structures, and changes in the activity of cell membrane enzymes [44]. Hoyto et al. demonstrated significant induction of lipid peroxidation after exposure to EMF in the mouse SH-SY5Y cell and L929 fibroblast cells [45]. Epidemiological studies have also suggested that oxidative damage to lipids in blood vessel walls may be a significant contributor to the development of atherosclerosis [46–48].

Studies generally focus on the brain, since cell phones are held close to the head during use. There is considerable evidence that EMF can affect neural functions in the human brain [50]. The relation between EMF and neurological disorders can be explained in terms of the heat shock response [51]. The heat shock protein (HSP) response is generally concerned with heat shock, exposure to heavy metals and environmental insults such as EMF. Generally, HSP is a marker in cells under stress. Living organisms generate stress proteins in order to survive environmental stressors. The heat shock response is regarded as a general response to a wide variety of stresses, such as oxidative stress [52]. In humans and other mammals, many environmental stimuli causes ultraviolet radiation [53], ionizing radiation [54] and laser radiation [55] are caused by cellular stresses and alter Hsp90 and 70 levels. Non-ionizing radiation also causes HSP changes in various tissues, including the brain [56], myocardium [57], testis [5] and skin [58]. Studies have described these findings as an adaptation or readjustment of cellular stress

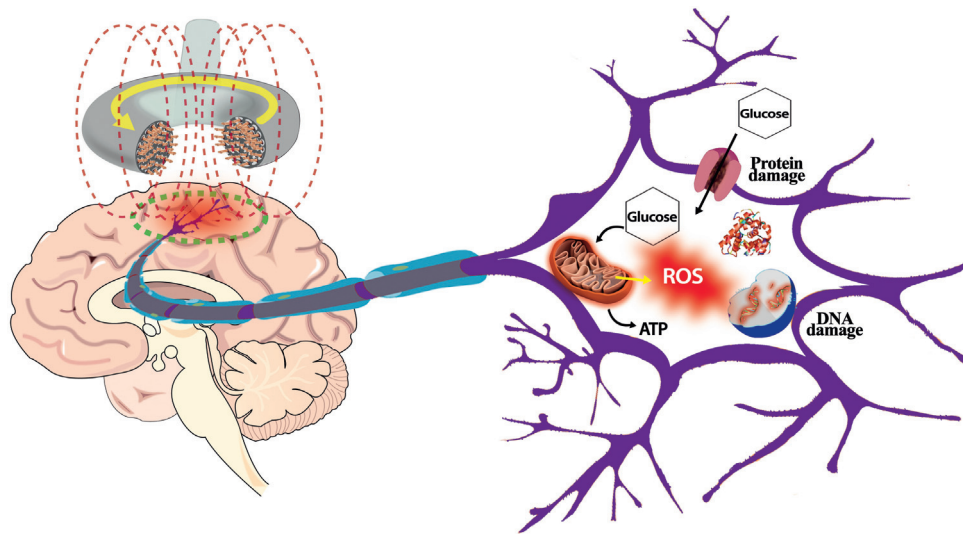


Fig 1. Reactive oxygen species generated by the effects of exposure to EMF can damage various cellular structures in neurons of the central nervous system [49].

proteins before preparing the cellular machinery for an adequate environmental change. Small, transitory readjustments of the circuits may thus decisively influence overall stress tolerance [59,60].

Low frequency (0–300 Hz) and RF (10 MHz–300 GHz) EMF has also been reported to alter the permeability of the blood–brain barrier [61–63]. At the same time, these changes in the blood–brain barrier may lead to excess accumulation of heavy metals and specifically of iron in the brain. This effect may trigger several neuronal disorders [64,65]. Some studies have reported that DNA damage and blood–brain barrier disruption is connected, and that autism spectrum conditions are associated with EMF exposure. The disruption of fertility and reproduction associated with EMF/RF may also be related to the increasing incidence of autism spectrum conditions [66–68].

Oxidative stress plays an important role in DNA damage process, general and specific gene expression and cell apoptosis. The brain has a high metabolic rate, making it more prone to damage by ROS and oxidative damage compared to other organs [69]. Excessive amounts of ROS in tissues may lead to necrosis, the death of neurons and neuronal damage in brain tissue, as well as to neurological disorders such as Alzheimer's disease, spinal cord injury, multiple sclerosis, and epilepsy [70] (Fig. 2). Several studies have observed neuronal damage and cellular losses caused by exposure to EMF in many regions of the brain, including the cortex, basal ganglia, hippocampus and cerebellum [71–75]. One epidemiological study determined an association between amyotrophic lateral sclerosis and exposure to high intensity EMF, but no correlation was observed with other neurodegenerative diseases [76]. Rubin et al. noted that the pain level of headache may increase during exposure but decreased immediately when exposure ceased [77]. Haynal and Regli suggested that exposure to extremely low frequency (ELF)-EMF may be linked to amyotrophic lateral sclerosis, a fatal neurodegenerative disorder [78]. Maskey et al. investigated the effects on the brain of 835-MHz over different exposure times and observed a significant loss of pyramidal cells in the CA1 region of the hippocampus [79]. Another case control study by Villeneuve et al. reported a 5.3-fold increased risk of one brain cancer type, glioblastoma, in individuals exposed to EMF, but no increased risk for other brain cancers [80].

Some studies have shown that microwave exposure failed to induce a detectable genotoxic effect by itself, and have reported interference with DNA-repair mechanisms [82–85]. Oxidative damage in DNA occurs as a result of interaction between free radi-

cals and DNA, with the addition of bases or abstractions of hydrogen atoms from sugar moiety. Modified nucleotides emerge as products of damage (8-OH-dG) when DNA is modified by the oxidative damage caused by reactive oxygen molecules [86]. These products are markers of oxidative stress measured using analytical methods [87,88]. Agarwal and Saleh and Aitken et al. have reported that ROS may have harmful effects on sperm DNA and other biomolecules, proteins and lipids, consequently leading to male infertility [89,90].

At the same time, men carrying phones in their pocket or on their belt and therefore, most of adverse effects of the EMF are seen in reproductive organs. Sepehrmanesh et al. showed that exposure to RF-EMF produces increases in testicular proteins in adults that are related to carcinogenic risk and reproductive damage [6]. Neuroendocrine changes caused by EMFs are a key factor in changing hormone functions [91]. Eroğlu et al. stated that exposure to cell phone radiation reduces the motility and changes the morphology of isolated sperm cells. They also discussed the effects of EMFs on female infertility [92]. Goldhaber et al. reported a significant increase in fetal abnormalities and spontaneous abortions in pregnant women exposed to EMF [93]. Many of these effects may occur due to hormonal changes [94,95].

Studies on the effects of EMF on tissues discussed here are set out in Tables 1 and 2.

4. The antioxidant defense system and EMF

Antioxidant defense systems have developed in organisms to control the formation of free radicals and to prevent the harmful effects of these molecules [122]. These antioxidants reduce or impair the damage mechanism of ROS via their free radical scavenging activities [123]. Two major mechanisms have been identified for antioxidants [124]. The first is a mechanism of chain disruption in which the primary antioxidant releases an electron to the free radical found in the systems. The second mechanism includes elimination of the initiators of species of ROS/reactive nitrogen (secondary antioxidants) by suppressing chain-initiating catalysts. Antioxidants may also impact on biological systems by various mechanisms involving electron releasing, metal ion chelation, co-antioxidants, or by maintaining the expression of genes [125]. If these antioxidant defense mechanisms are impaired through exposure to an agent that causes the overproduction of ROS, including EMF, antioxidants may not be sufficient or free radical formation may increase to such an extent that it overpowers the defense

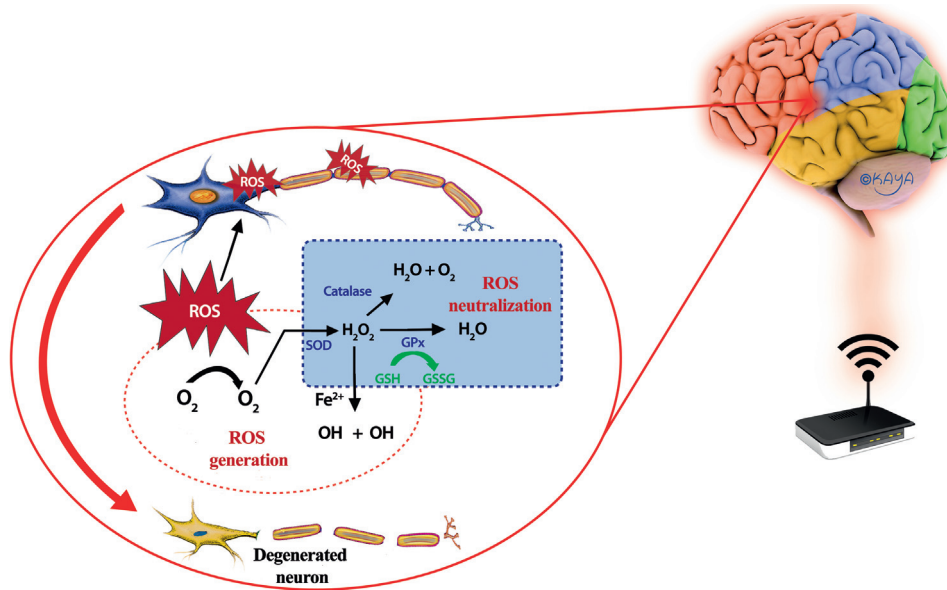


Fig. 2. The role of EMF emitted from several devices, depicting an increase in the generation of ROS and consequent oxidative stress in the central nervous system resulting from the inability of the antioxidant defense system to cope with this increase in ROS [81].

capabilities of antioxidants [10]. This is known as oxidative stress. EMFs can initiate various biochemical and physiological changes, including oxidative stress, in the systems of various species. Several studies in the literature show that plasma membrane receptors are possible targets for field interactions [126,127].

Generally, antioxidants have been divided into exogenous groups (carotene, C, and vitamin E), and endogenous groups (melatonin (MEL)), SOD, GSH-Px, CAT, including; protein (MEL), vitamins (vitamin C), trace elements (Mg, Se), complexes of compound, hydrophilic (ascorbic acid, urate, flavonoids) and hydrophobic (β -carotene, α -tocopherol) substances, with direct impacts (SOD, CAT), and indirect effects (vitamin E). Substances with functions concerning the membrane (vitamin A and E, β -carotene), circulation (vitamin C, amino acids and polyphenols), cytosol (co-enzyme Q10) are classified as antioxidants [122,128].

4.1. Glutathione

Glutathione (GSH) is an endogenous antioxidant and an important cellular defense agent against oxidative damage. GSH reacts with the free radicals in the cell and reduces the entry of hydrogen peroxides [129]. GSH also prevents the oxidation of sulphhydryl groups in the protein structure. GSH levels in tissues are often used as a marker for measuring radical damage. It acts as a substrate for antioxidant enzymes that causes resistance to radical-induced damage, behaving like a radical scavenger. GSH is especially important for the activity of glutathione peroxidase (GSH-Px), glutathione reductase (GR) and glutathione-S-transferase (GST). In the oxidative stress process, levels of GSH decrease, while glutathione disulfide increases. In this case, accumulation of hydrogen peroxide (H_2O_2) is scavenged by the effects of reductase and glutathione peroxidase (GSH-Px). GSH-Px is also an important enzyme, which prevents damage to phagocytic cells caused by free radicals. A decrease in GSH-Px activity leads to the accumulation of hydrogen peroxide and to cell damage. GSH-Px also prevents the initiation of lipid peroxidation [65]. EMF emitted by cellular phones is known to be related to a decreased level of GSH in brain tissue and blood [97]. However, a decreased level of blood GSH may possibly be explained by an elevated oxidation rate and use of GSH during the elimination of lipid and other peroxides [130]. Awad and Hassan investigated the brains of rats exposed to 900-MHz EMF from mobile phones

for 1 h/day for one week. They observed an increase in lipid peroxidation after exposure to mobile phones [131]. Aydın and Akar studied the effect of 900-MHz EMF for 2 h/day for 45 days on lymphoid organs in immature and mature rats. They reported that CAT and GPx activities decreased significantly compared to a control group. Similarly, an increase in lipid peroxidation and a concomitant demolition in GSH levels were seen in all lymphoid organs after EMF exposure, suggesting that increased levels of lipid peroxidation may have been a consequence of depleted GSH stores [32]. Luo et al. investigated that the whether the protective effects of LSPCs performed by oral gavage on oxidative stress injury induced by ELF-EMF exposure. According the results, GST activity was significantly decreased in the ELF-EMF group when compared with the control group. They found that LSPCs could effectively prohibit oxidative stress damage induced by ELF-EMF exposure, it may be related to the ability to remove free radicals and induce antioxidant enzyme activity [132]. Singh et al. investigated the biochemical mechanism of the interaction of 900-MHz mobile phone EMF with root formation in mung bean hypocotyls. The obtained results showed up regulation of the activities of antioxidant enzymes such as CAT and GR, which protect against oxidative damage induced by EMF [133]. Sepehrimanesh et al. studied that effect of 900-MHz electromagnetic field (EMF) exposure on rat serum and testes antioxidant enzyme levels. They observed that after 30 days exposure both SOD and GPx activities decreased in the long-time EMF exposure group [134]. In the other study RF-EMF exposure caused increase antioxidant stress response via increase of CAT and GR activity it lead to the generation of lipid and protein oxidative damage [135].

4.2. Catalase

CAT is a common enzyme present in organisms exposed to oxygen, such as vegetables, fruits and animals. It catalyzes the reaction that degrades hydrogen peroxide to water and oxygen. It is a crucial enzyme in the protection of the cell against oxidative damage caused by ROS. CAT exerts its peroxidase activity in vivo. It can also catalyze the reaction of oxidation, by hydrogen peroxide, of numerous metabolites and toxins, not excluding formaldehyde, formic acid, phenols, acetaldehyde and alcohols. Its basic function is to remove hydrogen peroxide and peroxide ROOH in molecular oxygen in order to prevent irreversible damage to the membranes

Table 1
Some experimental studies on the oxidative effects of EMF.

Reference	Biological endpoint	Results
Ghodbane et al. [96]	Kidney	In the study investigated that whether Static magnetic fields induces oxidative stress and apoptosis in rat tissues and to evaluate the possible protector effect of selenium (Se) and vitamin E (vit E) supplementation. In the results have been shown exposure to SMF induced oxidative stress in kidney that will be able prevented by treatment with Se or vit E.
Meral et al. [97]	Brain	890-915-MHz EMF emitted by cellular phones may generate oxidative stress. MDA levels increased and GSH level and CAT enzyme activity decreased, while vitamin A, E and D3 levels remained unchanged in the brain tissue of guinea pigs
Misa-Agustiño et al. [98]	Thymus	The thymus tissue exhibited several morphological changes, including increased distribution of blood vessels along with the appearance of red blood cells and hemorrhagic reticuloepithelial cells
Balci et al. [99]	Cornea and lens	To investigate the adverse effects of mobile-phone on the antioxidant balance in corneal and lens tissues and to observe any protective effects of vitamin C in this setting. The results of this study suggest that mobile telephone radiation leads to oxidative stress in corneal and lens tissues and that antioxidants such as vitamin C can help to prevent these effects.
Bodera et al. [100]	Antioxidant capacity of blood	EMF exposure at 1800 MHz significantly reduced antioxidant capacity in both healthy animals and those with paw inflammation
Ozorak et al. [101]	Kidney and testis	In the present study was investigated that the effects of both Wi-Fi and 900 and 1800 MHz EMF on oxidative stress and trace element levels in the kidney and testis of growing rats from pregnancy to 6 weeks of age. It has been observed Wi-Fi and mobile phone-induced EMR may cause precocious puberty and oxidative kidney and testis injury in growing rats.
Ozgur et al. [102]	Liver and kidney	RF exposure is reported to induce lipid peroxidation, accompanied by decreased activity of superoxide dismutase (SOD), myeloperoxidase (MPO) and glutathione peroxidase (GSH-Px), in various organs, such as guinea pig liver and rat kidney
İkinci et al. [103]	Spinal cord	The aim of this study was therefore to investigate changes in the spinal cords of male rat pups exposed to the effect of 900 MHz EMF. The study results showed that MDA and GSH levels in EMFG increased significantly while CAT and SOD levels decreased following application of 900-MHz EMF pathological changes may occur in the spinal cords of male rats following exposure to 900 MHz.
Gurler et al. [104]	Brain	In the study has been investigated that the oxidative damage and protective effect of garlic on rats exposed to low level of EMF at 2.45 GHz MWR. It may be concluded that EMF increases the DNA damage in both brain tissues and plasma of the rats whereas it increases protein oxidation only in plasma. It may also be argued that the use of garlic decreases these effects.
Türedi et al. [105]	Bladder	In the study investigated the effect on male rat bladder tissues of exposure to 900 MHz EMF applied on postnatal days 22-59, inclusive. In bladder tissue, degeneration in the transitional epithelium and stromal irregularity and an increase in cells tending to apoptosis were observed in EMFG.
Yan et al. [106]	Sperm	Rats exposed to 6 hours of daily cellular phone emissions for 18 weeks exhibited a significantly higher incidence of sperm cell death than control group rats.
Rajkovic et al. [107]	Thyroid gland	After significant morphophysiological changes caused by ELF-EMF exposure, the thyroid gland recovered morphologically, but not physiologically, during the investigated repair period.
Deniz et al. [108]	Kidney	In the results was observed the 900-MHz EMR cause to kidney damage and FA may exhibit a protective effect against the adverse effects of EMR exposure in terms of the total number of glomeruli.
Wang et al. [109]	Blood-testicle Barrier	In the study investigated the effect of electromagnetic pulse (EMP) exposure on cerebral micro vascular permeability in rats. It has been shown that exposure to 200 and 400 pulses (1 Hz) of EMP at 200 kV/m can increase the permeability of the blood-testicle barrier in mice
Avendaño et al. [110]	Sperm	Four-hour EMF exposure ex vivo to a wireless internet-connected laptop caused a significant decrease in progressive sperm motility and an increase in sperm DNA fragmentation
Narayanan et al. [111]	Human semen	RF exposure for one month induced oxidative stress in the rat brain, but the magnitude differed in the various regions studied, and RF-induced oxidative stress may be one underlying causes of the behavioral deficits seen in rats after RF exposure
Hanci [112]	Spleen and thymus	900 MHz EMF applied to spleen and thymus tissue caused significant histopathological changes at the TEM and LM levels

[136]. EMF is known to impact on biological systems by increasing ROS, which causes oxidative stress by altering the CAT levels of tissues [137–139]. Odaci et al. observed a decrease in CAT levels in an EMF-exposed group. Exposure to EMF during the prenatal period also caused oxidative stress in developing rat embryos. This oxidative stress persisted through postnatal day 21 [140]. Vuokko et al. reported that EMF exposure led to depression of antioxidant

systems because of raised lipid peroxidation and generation of free radicals [141]. Mobile phones triggered oxidative damage in the living cell by increasing the levels of xanthine oxidase and carbonyl group activity and reducing CAT activity. Treatment with MEL significantly prevents oxidative damage in the brain [142]. Özgüner et al. reported that EMF exposure leads to renal tissue damage by raising nitric oxide and malondialdehyde (MDA) levels [143].

Table 2
Some clinical studies of the oxidative effects of EMF.

Reference	Biological endpoint	Results
Lantow et al. [113]	Monocytes and lymphocytes	No significant ROS generation was measured in human cell lines exposed to 1800 MHz.
Baohong et al. [114]	Human blood lymphocytes	RF exposure for 1.5 and 4 h did not significantly exacerbate human lymphocyte DNA damage, but may reduce and increase DNA damage in human lymphocytes induced by ultraviolet C at 1.5 and 4 h incubation.
Ansarihadipour et al. [115]	Human blood proteins	EMF exacerbated oxidative damage to plasma proteins as well as conformational changes in Hb.
Wu et al. [35]	Human epithelial lens cells	RF at 4W/kg for 24 h significantly increased intracellular ROS and DNA damage.
Belyaev et al. [116]	Human blood lymphocytes	Decreased background levels of p53 binding protein 1 foci and may indicate a reduced accessibility of 53BP1 to antibodies because of stress-induced chromatin condensation.
Agarwal et al. [117]	Human ejaculated semen	900 MHz EMF emitted by mobile phones may cause oxidative stress in human semen.
Lewicka et al. [118]	Human blood platelets (in vivo)	The largest increase in ROS concentration vs. a control sample was observed after exposure to EMF of 220 V/m intensity for 60 min. The enzymatic activity of SOD-1 also decreased.
Lu et al. [119]	Human peripheral blood mononuclear cells	Cell apoptosis can be induced in human peripheral blood mononuclear cells by 900-MHz GSM radiofrequency electromagnetic field at a specific absorption rate of 0.4W/kg when exposure exceed 2 h.
De Iuliis et al. [120]	Human spermatozoa (in vitro)	Highly significant relationships were observed between SAR, the oxidative DNA damage bio-marker, 8-OH-dG, and DNA fragmentation after RF exposure.
Yao et al. [37]	Human lens epithelial cells	DNA damage was significantly increased by comet assay at 3 and 4 W/kg, whereas double strand breaks by histone variant foci were significantly increased only at 4 W/kg, while increased ROS levels were detected in the 3 and 4 W/kg groups.
Sefidbakht et al. [121]	Human embryonic kidney cells	Results showed that an increase in the activity of luciferase after 60 min of continuous exposure may be associated with a decrease in ROS levels caused by activation of the oxidative response.

4.3. Superoxide dismutase

SOD is an enzyme that catalyzes the reaction in which the toxic superoxide (O_2^-) radical is partitioned into molecular oxygen (O_2) or hydrogen peroxide (H_2O_2). Superoxide is generated as a by-product as a result of the oxygen metabolism, leading to several types of damage to cells. Three forms of SOD can be encountered in humans; SOD₁ is present in the cytoplasm, SOD₂ in the mitochondria, and SOD₃ in the extracellular compartment. SOD is present in the cytosol and mitochondria and inactivates the existing superoxide radicals, as well as protecting cells from the harmful effects of the superoxide radicals [144]. Research has shown that the rat brain is susceptible to the effects of exposure to ELF-EMF. Decreased CAT and SOD activity results in after exposure suggested that EMF might change the antioxidant levels of the brain [145]. Gambari et al. reported that 50-day exposure to EMF causes oxidative stress by increasing MDA levels and reducing SOD activity, and observed that treatment with vitamin E prevented oxidative stress and lipid peroxidation in the substantia nigra [146]. Another study reported decreased antioxidant enzyme levels and increased levels of ROS in the kidneys of rats exposed to 900-MHz EMF for 30 min/day for 1 month [143].

5. Antioxidants alleviate the potential risks of EMF exposure

When applied antioxidant supplemented with EMF exposure, improved the hydrophilic, lipophilic and enzymatic antioxidant blood capacity and partially compensated for these changes [147,148]. Vitamin E (tocopherol) is one of the most important such antioxidants. Compounds of vitamin E, including alpha, beta, gamma and delta tocopherols, are soluble in lipid. Vitamin E is stored in the liver and has many functions. Its main antioxidant function is to prevent lipid peroxidation [149]. Several studies have shown the beneficial effects of vitamin E observed by reducing alteration in antioxidant capacity against the harmful effects of EMF [150,151]. Ghambari et al. observed that exposure to 3-MT EMF led to oxidative stress by reducing SOD activity and reported

that treatment with vitamin E prevents the lipid peroxidation in the substantia nigra [146]. Mohammadnejad et al. studied ultrastructural changes in the thymus after exposure to EMF and investigated the protective effects of vitamin E in preventing these change. Their results demonstrated that exposure to EMF caused damage to the immune system and that vitamin E consumption can prevent ultrastructural alteration in tissue [152].

Vitamin B9 (folic acid and folate) is crucial for several functions in the human body, ranging from the production of nucleotides to homocysteine remethylation. In humans, folate is required for the body to make or repair DNA, and to methylate DNA, in addition to its function as a cofactor in various biological reactions. Moreover, this vitamin possesses antioxidant features [153]. It is especially crucial during periods involving quick cell division and cellular growth. Folic acid (FA) is particularly required in pregnancy and for infant brain development. It is also necessary for the formation of new cells [154]. Our previous study revealed that FA prevented the adverse effect of exposure to EMF by preventing reductions in cell numbers in the cerebellum and brain. Kivrak observed that EMF triggered oxidative damage by increasing the levels of CAT activity and reducing GPx activity. They also noticed that oxidative damage in the brain was significantly prevented by FA therapy [75] (Fig. 3).

MEL is a hormone secreted by the pineal gland and that is also known as N-acetyl-5-methoxy tryptamin. It functions as a first line of defense against oxidative stress [155]. This hormone acts together with other antioxidants such as CAT, SOD and GPx to increase the effectiveness of each antioxidant. As a free radical scavenger, it possesses amphiphilic properties and can easily cross cell membranes and the blood-brain barrier [156–158]. Previous studies have shown that MEL exhibits a protective effect against EMF-induced oxidative stress [159–161]. Koc et al. showed that MEL reduced neuronal damage in the hippocampus induced by 900-MHz EMF. Ozguner et al. showed that exposure to 900-MHz EMF led to mild skin alterations [162]. Ulubay et al. stated that exposure to 900-MHz EMF in the rat kidney during the prenatal period results not only in an increase in total kidney volume, but also in decreased numbers of glomeruli. The application of MEL was found to prevent the negative effects of EMF on the kidneys [148].

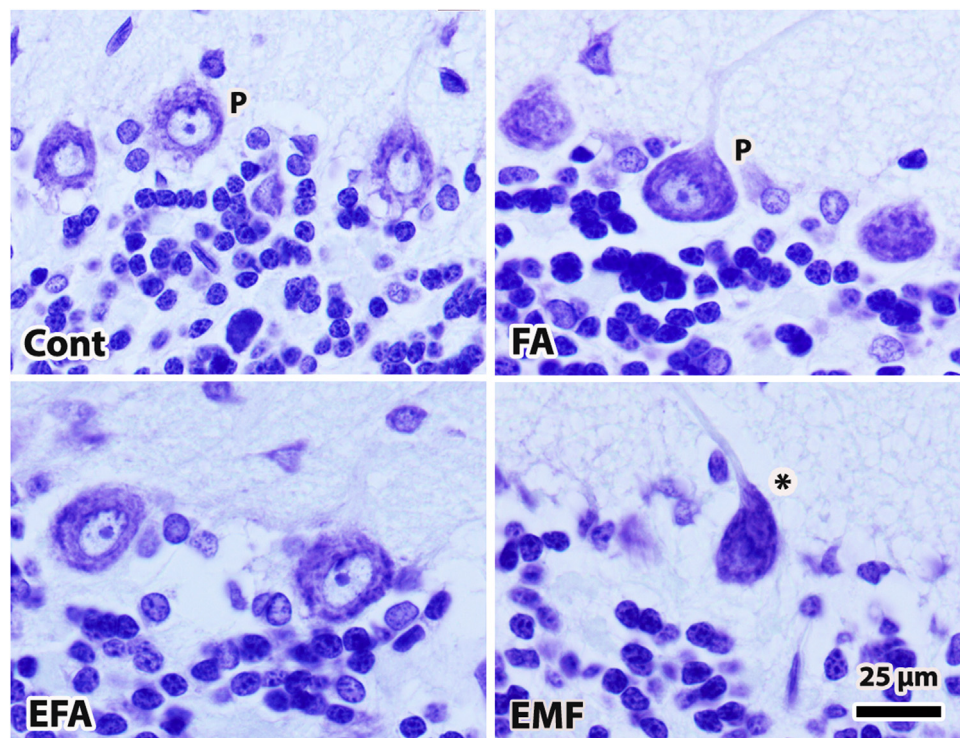


Fig. 3. Images of cerebellar tissues from the control (Cont), EMF exposure, FA and EMF + FA (EFA) groups. The letter P indicates healthy Purkinje cells in the Cont and FA groups. Necrosis of Purkinje cells is indicated with a star in the EMF group [72].

Lai and Singh demonstrated that MEL prevents EMF-induced DNA damage resulting from free radical generation in rat brain cells [31].

6. Conclusion

The biological effect of exposure to EMF is a subject of particular research interest. The results of the recent studies not only clearly demonstrate that EMF exposure triggers oxidative stress in various tissues, but also that it causes significant changes in levels of blood antioxidant markers. Fatigue, headache, decreased learning ability, and cognitive impairment are among the symptoms caused by EMF. The human body should therefore be protected against exposure to EMF because of the risks this can entail. As reported in many studies, people may use various antioxidants such as vitamin E, MEL and FA to prevent the potential adverse effects of exposure to EMF.

References

- [1] Fragopoulou AF, Koussoulakos SL, Margaritis LH. Cranial and postcranial skeletal variations induced in mouse embryos by mobile phone radiation. *Pathophysiology* 2010;17:169–77.
- [2] Megha K, Deshmukh PS, Banerjee BD, Tripathi AK, Abegaonkar MP. Microwave radiation induced oxidative stress, cognitive impairment and inflammation in brain of Fischer rats. *Indian J Exp Biol* 2012;50:889–96.
- [3] Challis LJ. Mechanisms for interaction between RF fields and biological tissue. *Bioelectromagnetics* 2005;(Suppl 7):S98–106.
- [4] Leszczynski D, Joenvaara S, Reivinen J, Kuokka R. Non-thermal activation of the hsp27/p38MAPK stress pathway by mobile phone radiation in human endothelial cells: molecular mechanism for cancer- and blood-brain barrier-related effects. *Differentiation* 2002;70:120–9.
- [5] Sepehrmanesh M, Kazempour N, Saeb M, Nazifi S. Analysis of rat testicular proteome following 30-day exposure to 900 MHz electromagnetic field radiation. *Electrophoresis* 2014;35:3331–8.
- [6] Sepehrmanesh M, Kazempour N, Saeb M, Nazifi S, Davis DL. Proteomic analysis of continuous 900-MHz radiofrequency electromagnetic field exposure in testicular tissue: a rat model of human cell phone exposure. *Environ Sci Pollut Res Int* 2017;24:13666–73.
- [7] Tkalec M, Malaric K, Pevalak-Kozlina B. Exposure to radiofrequency radiation induces oxidative stress in duckweed *Lemna minor* L. *Sci Total Environ* 2007;388:78–89.
- [8] Cui K, Luo X, Xu K, Ven Murthy MR. Role of oxidative stress in neurodegeneration: recent developments in assay methods for oxidative stress and nutraceutical antioxidants. *Prog Neuropsychopharmacol Biol Psychiatry* 2004;28:771–99.
- [9] Halliwell B. Role of free radicals in the neurodegenerative diseases: therapeutic implications for antioxidant treatment. *Drugs Aging* 2001;18:685–716.
- [10] Calcabrini C, Mancini U, De Bellis R, Diaz AR, Martinelli M, Cucchiari L, et al. Effect of extremely low-frequency electromagnetic fields on antioxidant activity in the human keratinocyte cell line NCTC 2544. *Biotechnol Appl Biochem* 2016.
- [11] Venugopal SK, Devaraj S, Yang T, Jialal I. alpha-tocopherol decreases superoxide anion release in human monocytes under hyperglycemic conditions via inhibition of protein kinase C-alpha. *Diabetes* 2002;51:3049–54.
- [12] Halliwell B. Oxidative stress and cancer: have we moved forward. *Biochem J* 2007;401:1–11.
- [13] Ames BN, Shigenaga MK, Hagen TM. Oxidants, antioxidants, and the degenerative diseases of aging. *Proc Natl Acad Sci USA* 1993;90:7915–22.
- [14] Basaga HS. Biochemical aspects of free-Radicals. *Biochem Cell Biol* 1990;68:989–98.
- [15] Stadtman ER, Oliver CN. Metal-catalyzed oxidation of proteins. *J Biol Chem* 1991;266:2005.
- [16] Feychting M, Ahlbom A. Magnetic fields and cancer in children residing near Swedish high-voltage power lines. *Am J Epidemiol* 1993;138:467–81.
- [17] Ozguner F, Altinbas A, Ozaydin M, Dogan A, Vural H, Kisioglu AN, et al. Mobile phone-induced myocardial oxidative stress: protection by a novel antioxidant agent caffeic acid phenethyl ester. *Toxicol Ind Health* 2005;21:223–30.
- [18] Valberg PA, van Deventer TE, Repacholi MH. Workgroup report: base stations and wireless networks-radiofrequency (RF) exposures and health consequences. *Environ Health Perspect* 2007;115:416–24.
- [19] Nishiyama HIM, Kato N. Relay-by-smartphone: realizing multihop device-to-device communications. *IEEE Com Mag* 2014;52:56–65.
- [20] Manikonda PK, Rajendra P, Devendranath D, Gunasekaran B, Channakeshava Aradhya RSS, et al. Influence of extremely low frequency magnetic fields on Ca²⁺ signaling and NMDA receptor functions in rat hippocampus. *Neurosci Lett* 2007;413:145–9.
- [21] Soderqvist F, Carlberg M, Hardell L. Use of wireless telephones and serum S100 B levels: a descriptive cross-sectional study among healthy Swedish adults aged 18–65 years. *Sci Total Environ* 2009;407:798–805.
- [22] Behari J. Biological responses of mobile phone frequency exposure. *Indian J Exp Biol* 2010;48:959–81.
- [23] Gherardini L, Ciuti G, Tognarelli S, Cinti C. Searching for the perfect wave: the effect of radiofrequency electromagnetic fields on cells. *Int J Mol Sci* 2014;15:5366–87.

- [24] Alberts B, Johnson A, Lewis J, Raff M, Roberts K, Walter P. Membrane Transport of Small Molecules and the Electrical Properties of Membranes. *Molecular Biology of the Cell*. 4th edition New York: Garland Science; 2002, pp. 651.
- [25] Challis LJ. Mechanisms for interaction between RF fields and biological tissue. *Bioelectromagnetics* 2005;S98–106.
- [26] Georgiou CD. Oxidative stress induced biological damage by low level EMFs: mechanism of free radical pair electron spinpolarization and biochemical amplification. *Eur J Oncol* 2010;5:66–113.
- [27] Lobo V, Patil A, Phatak A, Chandra N. Free radicals, antioxidants and functional foods: impact on human health. *Pharmacogn Rev* 2010;4:118–26.
- [28] Chen G, Upham BL, Sun W, Chang CC, Rothwell EJ, Chen KM, et al. Effect of electromagnetic field exposure on chemically induced differentiation of friend erythroleukemia cells. *Environ Health Perspect* 2000;108:967–72.
- [29] Park JE, Seo YK, Yoon HH, Kim CW, Park JK, Jeon S. Electromagnetic fields induce neural differentiation of human bone marrow derived mesenchymal stem cells via ROS mediated EGFR activation. *Neurochem Int* 2013;62:418–24.
- [30] Jajte J, Zmyslony M. [The role of melatonin in the molecular mechanism of weak, static and extremely low frequency (50 Hz) magnetic fields (ELF)]. *Med Pr* 2000;51:51–7.
- [31] Lai H, Singh NP. Magnetic-field-induced DNA strand breaks in brain cells of the rat. *Environ Health Perspect* 2004;112:687–94.
- [32] Aydin B, Akar A. Effects of a 900-MHz electromagnetic field on oxidative stress parameters in rat lymphoid organs, polymorphonuclear leukocytes and plasma. *Arch Med Res* 2011;42:261–7.
- [33] Dasdag S, Akdag MZ. The link between radiofrequencies emitted from wireless technologies and oxidative stress. *J Chem Neuroanat* 2016;75:85–93.
- [34] Zmyslony M, Politanski P, Rajkowska E, Szymczak W, Jajte J. Acute exposure to 930 MHz CW electromagnetic radiation in vitro affects reactive oxygen species level in rat lymphocytes treated by iron ions. *Bioelectromagnetics* 2004;25:324–8.
- [35] Wu W, Yao K, Wang KJ, Lu DQ, He JL, Xu LH, et al. Blocking 1800 MHz mobile phone radiation-induced reactive oxygen species production and DNA damage in lens epithelial cells by noise magnetic fields. *Zhejiang Da Xue Bao Yi Xue Ban* 2008;37:34–8.
- [36] Yao K, Wu W, Wang K, Ni S, Ye P, Yu Y, et al. Electromagnetic noise inhibits radiofrequency radiation-induced DNA damage and reactive oxygen species increase in human lens epithelial cells. *Mol Vis* 2008;14:964–9.
- [37] Yao K, Wu W, Yu Y, Zeng Q, He J, Lu D, et al. Effect of superposed electromagnetic noise on DNA damage of lens epithelial cells induced by microwave radiation. *Invest Ophthalmol Vis Sci* 2008;49:2009–15.
- [38] Oktem F, Ozguner F, Mollaoglu H, Koyu A, Uz E. Oxidative damage in the kidney induced by 900-MHz-emitted mobile phone: protection by melatonin. *Arch Med Res* 2005;36:350–5.
- [39] Friedman J, Kraus S, Hauptman Y, Schiff Y, Seger R. Mechanism of short-term ERK activation by electromagnetic fields at mobile phone frequencies. *Biochem J* 2007;405:559–68.
- [40] Fang YZ, Yang S, Wu G. Free radicals, antioxidants, and nutrition. *Nutrition* 2002;18:872–9.
- [41] Fridovich I. Fundamental aspects of reactive oxygen species, or what's the matter with oxygen. *Ann N Y Acad Sci* 1999;893:13–8.
- [42] Mattson MP. Metal-catalyzed disruption of membrane protein and lipid signaling in the pathogenesis of neurodegenerative disorders. *Ann N Y Acad Sci* 2004;1012:37–50.
- [43] Halliwell B. Free radicals and antioxidants: a personal view. *Nutr Rev* 1994;52:253–65.
- [44] Zmyslony M, Jajte JM. The role of free radicals in mechanisms of biological function exposed to weak, constant and net magnetic fields. *Med Pr* 1998;49:177–86.
- [45] Hoyto A, Luukkainen J, Juutilainen J, Naarala J. Proliferation, oxidative stress and cell death in cells exposed to 872 MHz radiofrequency radiation and oxidants. *Radiat Res* 2008;170:235–43.
- [46] Collins T. Endothelial nuclear factor-kappa B and the initiation of the atherosclerotic lesion. *Lab Invest* 1993;68:499–508.
- [47] Lusis AJ, Navab M. Lipoprotein oxidation and gene expression in the artery wall: new opportunities for pharmacologic intervention in atherosclerosis. *Biochem Pharmacol* 1993;46:2119–26.
- [48] Steinberg D, Parthasarathy S, Carew TE, Khoo JC, Witztum JL. Beyond cholesterol: modifications of low-density lipoprotein that increase its atherogenicity. *N Engl J Med* 1989;320:915–24.
- [49] Oh J, Lee YD, Wagers AJ. Stem cell aging: mechanisms, regulators and therapeutic opportunities. *Nat Med* 2014;870–80.
- [50] Croft RJ, Chandler JS, Burgess AP, Barry RJ, Williams JD, Clarke AR. Acute mobile phone operation affects neural function in humans. *Clin Neurophysiol* 2002;113:1623–32.
- [51] Kempson IM, Martin AL, Denman JA, French PW, Prestidge CA, Barnes TJ. Detecting the presence of denatured human serum albumin in an adsorbed protein monolayer using TOF-SIMS. *Langmuir* 2010;26:12075–80.
- [52] Wu C. Heat shock transcription factors: structure and regulation. *Annu Rev Cell Dev Biol* 1995;11:441–69.
- [53] Trautinger F, Kindas-Mugge I, Knobler RM, Honigsmann H. Stress proteins in the cellular response to ultraviolet radiation. *J Photochem Photobiol B* 1996;35:141–8.
- [54] Calini V, Urani C, Camatini M. Overexpression of HSP70 is induced by ionizing radiation in C3H 10T1/2 cells and protects from DNA damage. *Toxicol In Vitro* 2003;17:561–6.
- [55] Novoselova EG, Cherenkov DA, Glushkova OV, Novoselova TV, Chudnovskii VM, Iusupov VI, et al. Effect of low-intensity laser radiation (632.8 nm) on immune cells isolated from mice. *Biofizika* 2006;51:509–18.
- [56] Jorge-Mora MT, Folgueiras MA, Leiro-Vidal JM, Jorge-Barreiro FJ, Ares-Pena FJ, Lopez-Martin E. Exposure to 2.45 GHz microwave radiation provokes cerebral changes in induction of HSP90 heat shock protein in rat. *Prog Electromagn Res* 2010;100:351–79.
- [57] George I, Geddis MS, Lill Z, Lin H, Gomez T, Blank M, et al. Myocardial function improved by electromagnetic field induction of stress protein hsp 70. *J Cell Physiol* 2008;216:816–23.
- [58] Shi B, Farboud B, Nuccitelli R, Isseroff RR. Power-line frequency electromagnetic fields do not induce changes in phosphorylation, localization or expression of the 27-kilodalton heat shock protein in human keratinocytes. *Environ Health Perspect* 2003;111:281–8.
- [59] Ramaglia V, Buck LT. Time-dependent expression of heat shock proteins 70 and 90 in tissues of the anoxic western painted turtle. *J Exp Biol* 2004;207:3775–84.
- [60] Yang J. Frequency shifts in a piezoelectric body due to small amounts of additional mass on its surface. *IEEE Trans Ultrason Ferroelectr Freq Control* 2004;51:1199–202.
- [61] Grigor'ev IuG. The electromagnetic fields of cellular phones and the health of children and of teenagers (the situation requiring to take an urgent measure). *Radiats Biol Radioecol* 2005;45:442–50.
- [62] Oscar KJ, Hawkins TD. Microwave alteration of the blood-brain barrier system of rats. *Brain Res* 1977;126:281–93.
- [63] Nittby H, Grafstrom G, Eberhardt JL, Malmgren L, Brun A, Persson BR, et al. Radiofrequency and extremely low-frequency electromagnetic field effects on the blood-brain barrier. *Electromagn Biol Med* 2008;27:103–26.
- [64] Castelnau PA, Garrett RS, Palinski W, Witztum JL, Campbell IL, Powell HC. Abnormal iron deposition associated with lipid peroxidation in transgenic mice expressing interleukin-6 in the brain. *J Neuropathol Exp Neurol* 1998;57:268–82.
- [65] Thompson KJ, Shoham S, Connor JR. Iron and neurodegenerative disorders. *Brain Res Bull* 2001;55:155–64.
- [66] Herbert MR, Sage C. Autism and EMF? Plausibility of a pathophysiological link—Part I. *Pathophysiology* 2013;20:191–209.
- [67] Thomas RH, Meeking MM, Mephum JR, Tichenoff L, Possmayer F, Liu S, et al. The enteric bacterial metabolite propionic acid alters brain and plasma phospholipid molecular species: further development of a rodent model of autism spectrum disorders. *J Neuroinflammation* 2012;9:153.
- [68] Onore CE, Nordahl CW, Young GS, Van de Water JA, Rogers SJ, Ashwood P. Levels of soluble platelet endothelial cell adhesion molecule-1 and P-selectin are decreased in children with autism spectrum disorder. *Biol Psychiatry* 2012;72:1020–5.
- [69] Ozmen I, Naziroglu M, Alici HA, Sahin F, Cengiz M, Eren I. Spinal morphine administration reduces the fatty acid contents in spinal cord and brain by increasing oxidative stress. *Neurochem Res* 2007;32:19–25.
- [70] Deshmukh PS, Megha K, Banerjee BD, Ahmed RS, Chandra S, Abegaonkar MP, et al. Detection of low level microwave radiation induced deoxyribonucleic acid damage vis-a-vis genotoxicity in brain of fischer rats. *Toxicol Int* 2013;20:19–24.
- [71] Odaci E, Bas O, Kaplan S. Effects of prenatal exposure to a 900 MHz electromagnetic field on the dentate gyrus of rats: a stereological and histopathological study. *Brain Res* 2008;1238:224–9.
- [72] Erdem Koc, Kaplan S, Altun G, Gumus H, Gulsun Deniz O, Aydin I, et al. Neuroprotective effects of melatonin and omega-3 on hippocampal cells prenatally exposed to 900 MHz electromagnetic fields. *Int J Radiat Biol* 2016;92:590–5.
- [73] Volkow ND, Tomasi D, Wang GJ, Vaska P, Fowler JS, Telang F, et al. Effects of cell phone radiofrequency signal exposure on brain glucose metabolism. *JAMA* 2011;305:808–13.
- [74] Tasset I, Medina FJ, Jimena I, Aguera E, Gascon F, Feijoo M, et al. Neuroprotective effects of extremely low-frequency electromagnetic fields on a Huntington's disease rat model: effects on neurotrophic factors and neuronal density. *Neuroscience* 2012;209:54–63.
- [75] Kivrak EG. Investigation of the effects of boswellia sacra and folic acid on hippocampus with electromagnetic fields Master thesis. Samsun, Turkey: Ondokuz Mayıs University; 2014.
- [76] Johansen C. Electromagnetic fields and health effects—epidemiological studies of cancer, diseases of the central nervous system and arrhythmia-related heart disease. *Scand J Work Environ Health* 2004;30(Suppl 1):1–30.
- [77] Rubin GJ, Hahn G, Everitt BS, Cleare AJ, Wessely S. Are some people sensitive to mobile phone signals: within participants double blind randomised provocation study. *BMJ* 2006;332:886–91.
- [78] Haynal A, Regli F. Amyotrophic lateral sclerosis associated with accumulated electric injury. *Confin Neurol* 1964;24:189–98.
- [79] Maskey D, Kim M, Aryal B, Pradhan J, Choi IY, Park KS, et al. Effect of 835 MHz radiofrequency radiation exposure on calcium binding proteins in the hippocampus of the mouse brain. *Brain Res* 2010;1313:232–41.
- [80] Villeneuve PJ, Agnew DA, Johnson KC, Mao Y. Canadian Cancer Registries Epidemiology Research G. Brain cancer and occupational exposure to magnetic fields among men: results from a Canadian population-based case-control study. *Int J Epidemiol* 2002;31:210–7.

- [81] Othman SB, Yabe T. Use of hydrogen peroxide and peroxy radicals to induce oxidative stress in neuronal cells. *Reviews in Agricultural Science* 2015;3:40–5.
- [82] Kesari KK, Kumar S, Behari J. 900-MHz microwave radiation promotes oxidation in rat brain. *Electromagn Biol Med* 2011;30:219–34.
- [83] Atlı Sekeroglu Z, Akar A, Sekeroglu V. Evaluation of the cytogenotoxic damage in immature and mature rats exposed to 900 MHz radiofrequency electromagnetic fields. *Int J Radiat Biol* 2013;89:985–92.
- [84] Liu C, Gao P, Xu SC, Wang Y, Chen CH, He MD, et al. Mobile phone radiation induces mode-dependent DNA damage in a mouse spermatocyte-derived cell line: a protective role of melatonin. *Int J Radiat Biol* 2013;89:993–1001.
- [85] Ruediger HW. Genotoxic effects of radiofrequency electromagnetic fields. *Pathophysiology* 2009;16:89–102.
- [86] Kryston TB, Georgiev AB, Pissis P, Georgakilas AG. Role of oxidative stress and DNA damage in human carcinogenesis. *Mutat Res* 2011;711:193–201.
- [87] Henderson PT, Evans MD, Cooke MS. Salvage of oxidized guanine derivatives in the (2'-deoxy) ribonucleotide pool as source of mutations in DNA. *Mutat Res* 2010;703:11–7.
- [88] Tothova L, Kamodyova N, Cervenka T, Celec P. Salivary markers of oxidative stress in oral diseases. *Front Cell Infect Microbiol* 2015;5:73.
- [89] Aitken RJ, Harkiss D, Buckingham DW. Analysis of lipid peroxidation mechanisms in human spermatozoa. *Mol Reprod Dev* 1993;35:302–15.
- [90] Agarwal A, Saleh RA. Role of oxidants in male infertility: rationale, significance, and treatment. *Urol Clin North Am* 2002;29:817–27.
- [91] Nelson JF, Karelus K, Bergman MD, Felicio LS. Neuroendocrine involvement in aging: evidence from studies of reproductive aging and caloric restriction. *Neurobiol Aging* 1995;16:837–43, discussion 55–6.
- [92] Eroglu O, Oztas E, Yildirim I, Kir T, Aydur E, Komesli G, et al. Effects of electromagnetic radiation from a cellular phone on human sperm motility: an in vitro study. *Arch Med Res* 2006;37:840–3.
- [93] Goldhaber MK, Polen MR, Hiatt RA. The risk of miscarriage and birth defects among women who use visual display terminals during pregnancy. *Am J Ind Med* 1988;13:695–706.
- [94] Forgacs Z, Somosy Z, Kubinyi G, Bakos J, Hudak A, Surjan A, et al. Effect of whole-body 1800 MHz GSM-like microwave exposure on testicular steroidogenesis and histology in mice. *Reprod Toxicol* 2006;22:111–7.
- [95] Ozguner M, Koyu A, Cesur G, Ural M, Ozguner F, Gokcimen A, et al. Biological and morphological effects on the reproductive organ of rats after exposure to electromagnetic field. *Saudi Med J* 2005;26:405–10.
- [96] Ghodbane SLA, Ammari M, Sakly M, Abdelmelek H. Does static magnetic field-exposure induced oxidative stress and apoptosis in rat kidney and muscle? Effect of vitamin E and selenium supplementations. *Gen Physiol Biophys* 2015;34:23–32.
- [97] Meral I, Mert H, Mert N, Deger Y, Yoruk I, Yetkin A, et al. Effects of 900-MHz electromagnetic field emitted from cellular phone on brain oxidative stress and some vitamin levels of guinea pigs. *Brain Res* 2007;1169:120–4.
- [98] Misa-Agustino MJ, Leiro-Vidal JM, Gomez-Amoza JL, Jorge-Mora MT, Jorge-Barreiro FJ, Salas-Sanchez AA, et al. EMF radiation at 2450 MHz triggers changes in the morphology and expression of heat shock proteins and glucocorticoid receptors in rat thymus. *Life Sci* 2015;127:1–11.
- [99] Balci M, Devrim E, Durak I. Effects of mobile phones on oxidant/antioxidant balance in cornea and lens of rats. *Curr Eye Res* 2007;32:21–5.
- [100] Boder P, Stankiewicz W, Zawada K, Antkowiak B, Paluch M, Kieliszek J, et al. Changes in antioxidant capacity of blood due to mutual action of electromagnetic field (1800 MHz) and opioid drug (tramadol) in animal model of persistent inflammatory state. *Pharmacol Rep* 2013;65:421–8.
- [101] Ozorak A, Naziroglu M, Celik O, Yuksek M, Ozelcik D, Ozkaya MO, et al. Wi-Fi (2.45 GHz)- and mobile phone (900 and 1800 MHz)-Induced risks on oxidative stress and elements in kidney and testis of rats during pregnancy and the development of offspring. *biol trace elem. Res* 2013;156:221–9.
- [102] Ozgur E, Guler G, Seyhan N. Mobile phone radiation-induced free radical damage in the liver is inhibited by the antioxidants N-acetyl cysteine and epigallocatechin-gallate. *Int J Radiat Biol* 2010;86:935–45.
- [103] Ikinici A, Mercantepe T, Unal D, Erol HS, Sahin A, Aslan A, et al. Morphological and antioxidant impairments in the spinal cord of male offspring rats following exposure to a continuous 900 MHz electromagnetic field during early and mid-adolescence. *J Chem Neuroanat* 2016;75:99–104.
- [104] Gurler HS, Bilgici B, Akar AK, Tomak L, Bedir A. Increased DNA oxidation (8-OHdG) and protein oxidation (AOPP) by low level electromagnetic field (2.45 GHz) in rat brain and protective effect of garlic. *Int J Radiat Biol* 2014;90:892–6.
- [105] Turedi S, Kerimoglu G, Mercantepe T, Odaci E. Biochemical and pathological changes in the male rat kidney and bladder following exposure to continuous 900-MHz electromagnetic field on postnatal days 22–59. *Int J Radiat Biol* 2017;1–10.
- [106] Yan JG, Agresti M, Bruce T, Yan YH, Granlund A, Matloub HS. Effects of cellular phone emissions on sperm motility in rats. *Fertil Steril* 2007;88:957–64.
- [107] Rajkovic V, Matavulj M, Gledic D, Lazetic B. Evaluation of rat thyroid gland morphophysiological status after three months exposure to 50 Hz electromagnetic field. *Tissue Cell* 2003;35:223–31.
- [108] Deniz OG, Kivrak EG, Kaplan AA, Altunkaynak BZ. Effects of folic acid on rat kidney exposed to 900 MHz electromagnetic radiation. *JMAU* 2017;900 (in press).
- [109] Wang XW, Ding GR, Shi CH, Zhao T, Zhang J, Zeng LH, et al. Effect of electromagnetic pulse exposure on permeability of blood-testicle barrier in mice. *Biomed Environ Sci* 2008;21:218–21.
- [110] Avendano C, Mata A, Sarmiento CAS, Doncel GF. Use of laptop computers connected to internet through Wi-Fi decreases human sperm motility and increases sperm DNA fragmentation. *Fertil Steril* 2012;97:39–U93.
- [111] Narayanan SN, Kumar RS, Kedage V, Nalini K, Nayak S, Bhat PG. Evaluation of oxidant stress and antioxidant defense in discrete brain regions of rats exposed to 900 MHz radiation. *Bratisl Med J* 2014;115:260–6.
- [112] Hanci H, Turedi S, Topal Z, Mercantepe T, Bozkurt I, Kaya H, et al. Can prenatal exposure to a 900 MHz electromagnetic field affect the morphology of the spleen and thymus, and alter biomarkers of oxidative damage in 21-day-old male rats? *Biotech Histochem* 2015;90:535–43.
- [113] Lantow M, Lupke M, Frahm J, Mattsson MO, Kuster N, Simko M. ROS release and Hsp70 expression after exposure to 1,800 MHz radiofrequency electromagnetic fields in primary human monocytes and lymphocytes. *Radiat Environ Biophys* 2006;45:55–62.
- [114] Baohong W, Lifeng J, Lanjuan L, Jianlin L, Deqiang L, Wei Z, et al. Evaluating the combinative effects on human lymphocyte DNA damage induced by ultraviolet ray C plus 1.8 GHz microwaves using comet assay in vitro. *Toxicology* 2007;232:311–6.
- [115] Ansarihidipour H, Bayatiani M. Influence of electromagnetic fields on lead toxicity: a study of conformational changes in human blood proteins. *Iran Red Crescent Med J* 2016;18:e28050.
- [116] Belyaev IY, Hillert L, Protopopova M, Tamm C, Malmgren LO, Persson BR, et al. 915 MHz microwaves and 50 Hz magnetic field affect chromatin conformation and 53BP1 foci in human lymphocytes from hypersensitive and healthy persons. *Bioelectromagnetics* 2005;26:173–84.
- [117] Agarwal A, Desai NR, Makker K, Varghese A, Mouradi R, Sabaneh E, et al. Effects of radiofrequency electromagnetic waves (RF-EMW) from cellular phones on human ejaculated semen: an in vitro pilot study. *Fertil Steril* 2009;92:1318–25.
- [118] Lewicka M, Henrykowska GA, Pacholski K, Smigielski J, Rutkowski M, Dziedziczak-Buczynska M, et al. The effect of electromagnetic radiation emitted by display screens on cell oxygen metabolism – in vitro studies. *Arch Med Sci* 2015;11:1330–9.
- [119] Lu YS, Huang BT, Huang YX. Reactive oxygen species formation and apoptosis in human peripheral blood mononuclear cell induced by 900 MHz mobile phone radiation. *Oxid Med Cell Longev* 2012;2012:740280.
- [120] De Iulius GN, Newey RJ, King BV, Aitken RJ. Mobile phone radiation induces reactive oxygen species production and DNA damage in human spermatozoa in vitro. *PLoS One* 2009;4:e6446.
- [121] Sefidbakht Y, Moosavi-Movahedi AA, Hosseinkhani S, Khodaghali F, Torkzadeh-Mahani M, Foolad F, et al. Effects of 940 MHz EMF on bioluminescence and oxidative response of stable luciferase producing HEK cells. *Photochem Photobiol Sci* 2014;13:1082–92.
- [122] Goraca A, Ciejk A, Piechota A. Effects of extremely low frequency magnetic field on the parameters of oxidative stress in heart. *J Physiol Pharmacol* 2010;61:333–8.
- [123] Halliwell B. How to characterize an antioxidant- an update. *Biochem Soc Symp* 1995;61:73–101.
- [124] Rice-Evans CA, Diplock AT. Current status of antioxidant therapy. *Free Radic Biol Med* 1993;15:77–96.
- [125] Krinsky NI. Mechanism of action of biological antioxidants. *Proc Soc Exp Biol Med* 1992;200:248–54.
- [126] Di Loreto S, Falone S, Caracciolo V, Sebastiani P, D'Alessandro A, Mirabilio A, et al. Fifty hertz extremely low-frequency magnetic field exposure elicits redox and trophic response in rat-cortical neurons. *J Cell Physiol* 2009;219:334–43.
- [127] Sun W, Gan Y, Fu Y, Lu D, Chiang H. An incoherent magnetic field inhibited EGF receptor clustering and phosphorylation induced by a 50-Hz magnetic field in cultured FL cells. *Cell Physiol Biochem* 2008;22:507–14.
- [128] E.N. Antioxidant defenses in eukaryotic cells. Basel, Switzerland: Birkhauser Verlag; 1993.
- [129] Zhao X, Alexander JS, Zhang S, Zhu Y, Sieber NJ, Aw TY, et al. Redox regulation of endothelial barrier integrity. *Am J Physiol Lung Cell Mol Physiol* 2001;281:L879–86.
- [130] Aslan I, Meral I. Effect of oral vitamin E supplementation on oxidative stress in guinea-pigs with short-term hypothermia. *Cell Biochem Funct* 2007;25:711–5.
- [131] Awad SM, Hassan NS. Health Risks of electromagnetic radiation from mobile phone on brain of rats. *Journal of Applied Sciences Research* 2008;4:1994–2000.
- [132] Luo X, Chen M, Duan Y, Duan W, Zhang H, He Y, et al. Chemoprotective action of lotus seedpod procyanidins on oxidative stress in mice induced by extremely low-frequency electromagnetic field exposure. *Biomed Pharmacother* 2016;82:640–8.
- [133] Singh HP, Sharma VP, Batish DR, Kohli RK. Cell phone electromagnetic field radiations affect rhizogenesis through impairment of biochemical processes. *Environ Monit Assess* 2012;184:1813–21.
- [134] Sepehrimanesh M, Nazifi S, Saeb M, Kazemipour N. Effect of 900 MHz radiofrequency electromagnetic field exposure on serum and testicular tissue antioxidantenzymes of rat. *Online Journal of Veterinary Research* 2016;20(9):617–24.

- [135] Tkalec M, Stambuk A, Srut M, Malaric K, Klobucar GI. Oxidative and genotoxic effects of 900 MHz electromagnetic fields in the earthworm *Eisenia fetida*. *Ecotoxicol Environ Saf* 2013;90:7–12.
- [136] Lanir A, Schejter A. On the sixth coordination position of beef liver catalase. *Febs Lett* 1975;55:254–6.
- [137] Ozturk A, Baltaci AK, Mogulkoc R, Oztekin E. Zinc prevention of electromagnetically induced damage to rat testicle and kidney tissues. *Biol Trace Elem Res* 2003;96:247–54.
- [138] Martinez-Samano JTP, Rez-Oropeza MA, Elias-Vinas D, Verdugo-Díaz L. Effects of acute electromagnetic field exposure and movement restraint on antioxidant system in liver, heart, kidney and plasma of Wistar rats: a preliminary report. *Int J Radiat Biol* 2010;86:1088–94.
- [139] Devrim E, Ergüder I, Kiliçoğlu B, Yaykasi E, Cetin R, Durak I. Effects of electromagnetic radiation use on oxidant/antioxidant status and DNA turn-over enzyme activities in erythrocytes and heart, kidney, liver, and ovary tissues from rats: possible protective role of vitamin C. *Toxicol Mech Methods* 2008;18:679–83.
- [140] Odaci E, Unal D, Mercantepe T, Topal Z, Hanci H, Turedi S, et al. Pathological effects of prenatal exposure to a 900 MHz electromagnetic field on the 21-day-old male rat kidney. *Biotech Histochem* 2015;90:93–101.
- [141] Kinnula VL, Paakko P, Soini Y. Antioxidant enzymes and redox regulating thiol proteins in malignancies of human lung. *FEBS Lett* 2004;569:1–6.
- [142] Sokolovic D, Djindjic B, Nikolic J, Beljakovic G, Pavlovic D, Kocic G, et al. Melatonin reduces oxidative stress induced by chronic exposure of microwave radiation from mobile phones in rat brain. *J Radiat Res* 2008;49:579–86.
- [143] Ozguner F, Oktem F, Ayata A, Koyu A, Yilmaz HR. A novel antioxidant agent caffeic acid phenethyl ester prevents long-term mobile phone exposure-induced renal impairment in rat Prognostic value of malondialdehyde, N-acetyl-beta-D-glucosaminidase and nitric oxide determination. *Mol Cell Biochem* 2005;277:73–80.
- [144] Fang YZ, Yang S, Wu GY. Free radicals, antioxidants, and nutrition. *Nutrition* 2002;18:872–9.
- [145] Martinez-Samano J, Torres-Duran PV, Juarez-Oropeza MA, Verdugo-Diaz L. Effect of acute extremely low frequency electromagnetic field exposure on the antioxidant status and lipid levels in rat brain. *Arch Med Res* 2012;43:183–9.
- [146] Ghanbari AA, Shabani K, Mohammad nejad D. protective effects of vitamin e consumption against 3MT electromagnetic field effects on oxidative parameters in substantia nigra in rats. *Basic Clin Neurosci* 2016;7:315–22.
- [147] de Moffarts B, Kirschvink N, Art T, Pincemail J, Lekeux P. Effect of oral antioxidant supplementation on blood antioxidant status in trained thoroughbred horses. *Vet J* 2005;169:65–74.
- [148] Ulubay M, Yahyazadeh A, Deniz OG, Kivrak EG, Altunkaynak BZ, Erdem G, et al. Effects of prenatal 900 MHz electromagnetic field exposures on the histology of rat kidney. *Int J Radiat Biol* 2015;91:35–41.
- [149] Ralston NVC, Ralston CR, Blackwell JL, Raymond LJ. Dietary and tissue selenium in relation to methylmercury toxicity. *Neurotoxicology* 2008;29:802–11.
- [150] Zhang J, Zhang YH, Jiang RP, Lian ZS, Wang H, Luo R, et al. Protective effects of vitamin E against electromagnetic radiation from cell phones in pregnant and fetal rats' brain tissues. *Journal of Shandong University (Health Sciences)* 2011;9:9–14.
- [151] Oral B, Guney M, Ozguner F, Karahan N, Mungan T, Comlekci S, et al. Endometrial apoptosis induced by a 900-MHz mobile phone: preventive effects of vitamins E and C. *Adv Ther* 2006;23:957–73.
- [152] Mohammadnejad D, Rad JS, Azami A, Lotfi A. Role of vitamin E in prevention of damages in the thymus induced by electromagnetic field: ultrastructural and light microscopic studies. *Bulletin of the Veterinary Institute in Pulawy* 2011;55:111–5.
- [153] Traber MG. Vitamin E regulatory mechanisms. *Annu Rev Nutr* 2007;27:347–62.
- [154] Wang X, Fenech M. A comparison of folic acid and 5-methyltetrahydrofolate for prevention of DNA damage and cell death in human lymphocytes in vitro. *Mutagenesis* 2003;18:81–6.
- [155] Hardeland R, Pandi-Perumal SR, Cardinali DP. Melatonin. *Int J Biochem Cell Biol* 2006;38:313–6.
- [156] Hardeland R. Antioxidative protection by melatonin: multiplicity of mechanisms from radical detoxification to radical avoidance. *Endocrine* 2005;27:119–30.
- [157] Tan DX, Poeggeler B, Manchester LC, Reiter RJ. Melatonin: a potent, endogenous hydroxyl radical scavenger. *Endocrine J* 1993;1:57–60.
- [158] DA WN Lowes, Murphy MP, Galley HF. Antioxidants that protect mitochondria reduce interleukin-6 and oxidative stress, improve mitochondrial function, and reduce biochemical markers of organ dysfunction in a rat model of acute sepsis. *Anaesth* 2013;110:472–80.
- [159] Reiter RJ, Herman TS, Meltz ML. Melatonin and radioprotection from genetic damage: in vivo/in vitro studies with human volunteers. *Mutat Res* 1996;371:221–8.
- [160] Reiter RJ, Herman TS, Meltz ML. Melatonin reduces gamma radiation-induced primary DNA damage in human blood lymphocytes. *Mutat Res* 1998;397:203–8.
- [161] Shirazi A, Ghobadi G, Ghazi-Khansari M. A radiobiological review on melatonin: a novel radioprotector. *J Radiat Res* 2007;48:263–72.
- [162] Ozguner F, Aydin G, Mollaoglu H, Gokalp O, Koyu A, Cesur G. Prevention of mobile phone induced skin tissue changes by melatonin in rat: an experimental study. *Toxicol Ind Health* 2004;20:133–9.

Effect of High Voltage Transmission Lines on Human Health, Plant Life, and Animal Activity

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Abstract- Due to increase in energy cost of transmission and new sources of energy, high voltage transmission becomes the most economical for the transfer of large amounts of electrical power because the higher the transmission voltage, the more efficient and cheaper the transmission. Due to increase in population, the towns are expanding, and naturally result in the construction of buildings near high voltage power lines. Simultaneously, the related public health and other detrimental effects on human, plant, and animal health crop up. This paper outlines the health effects of high voltage AC transmission and high voltage DC transmission on humans, plants, and animals based on epidemiologic studies. Due to increase in power demand because of population explosion, the need for transmitting huge amounts of power over long distances has increased. This paper gives the reader an in-depth analysis of all the effects of high voltage transmission on any living being. **There are long-term effects and short-term effects on all living beings.** Large transmission lines with high voltage and high current levels produce electric and magnetic field in the neighborhood. This paper also describes, in detail, the effects of magnetic, electric field, and electromagnetic field on human life, animal life, and plant life. This paper also elucidates on the methods to reduce the adverse effects caused by these fields. There are many supporting documents and research papers in favor of and against the harmful effects of these high voltage transmission lines. Therefore, there is a controversy discussion regarding these effects, involving government regulation policy and power companies.

shielding, grounding, compaction, human health, plant health, animal health.

1. INTRODUCTION

There are two fields associated with a transmission line. They are: electric field and magnetic field. Together, they are called as electromagnetic field or EMF. They occur naturally as a result of power generation, power transmission, power distribution and use of electric power. Each has its own effects on the health of different living organisms and they are discussed in detail in the upcoming paragraphs.

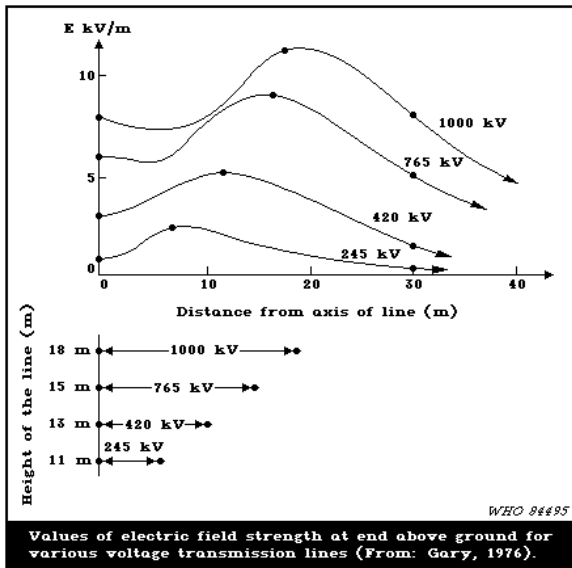
1.1. ELECTRIC FIELD

Electric field exists whenever a positive and negative electrical charge is present. They exert forces on other charges within the field. The strength of the electric field is measured in Volts per Meter V/m or in kV/m. The intensity of the electric field depends upon the following factors:

- Actual transmission voltage
- Distance between conductors in the ground.
- The phase spacing if you have two circuits next to each other as well as geometric configuration of the conductors.
- By the surrounding environment like tall objects such as trees, skyscrapers, fences, etc.
- The transmission center line tangential distance.

Keywords: high voltage, AC Transmission, DC Transmission, health effects of high voltage, line

- The elevation of the point of measurement



with respect to ground.

Chart 1: Effect of Voltage at different distances from axis of line

The electric field in a power line varies very little because the voltage essentially remains constant.

Each power line runs along a corridor of land called easement. The width of the easement is determined by the electrical load on the system. Public access to an easement is permitted but building and long term occupation are not allowed. At the edge of the easement, the EMFs are appreciably lower than at the center. The WHO limits are not exceeded anywhere within the easement. The EMFs outside the easement are consequently well below these limits. For example, for a typical 330kV transmission tower, the easement width is 60m.

Note: The electric field exists even when there is no current flowing.

1.2. MAGNETIC FIELD

The magnetic field from a power line can vary widely because the current in the wires depends upon the amount of power consumed. There are two basic 50Hz magnetic field, passive magnetic field and

active magnetic field. The magnetic field depends on the following factors:

- The ratings of current passing in the conductors. For example, typical lines-average current of 700A, largest line- average current of 4000A.
- Clearance of the line. We observe that maximum field occur underneath the conductor, and falls rapidly with distance on either side.
- Phasing of the conductors like conductor spacing, phase positioning, and phase balancing affects the magnetic field. The phase positioning are of two types, untransposed phasing and transposed phasing. Untransposed phasing is where the phases on both sides of the line are in the same order from top to bottom and we have a magnetic field which decreases with inverse-square of the distance. Transposed phasing is where the phases of one side are opposite order to the others on the second side. The magnetic field decreases inversely proportional to the cube of the distance.

Magnetic field are the result of motion of electric charge or current when there is a current flowing through a power line. The magnetic field lines run in circles around the conductor. The magnetic field are usually measure in Tesla.

2. ELECTROMAGNETIC FIELD EFFECT ON HUMAN BEINGS

The human body is composed of some biological materials like blood, bones, brain, lungs, etc. The permeability of the human body is equal to the permeability of the air, but within the human body it has different electromagnetic values at a certain frequency.

The human body also contains free electric charges which are ion rich fluids like blood and limb, which move in response to forces exerted by charges on and currents flowing in nearby power lines. This process

that produce these body currents are called electric and magnetic induction.

In electric induction charges on power line attract or repel free charges within the body (our body contains both positive and negative charges). Since the body fluids are good conductors of electricity, charges in the body move to the surface under the influence of electric force. For example, a positively charged overhead transmission line induces negative charges to flow through the surfaces on the upper part of the body. Similarly, negative charges induces positive charges. Therefore, the charge on the power lines alternates between positive and negative many times in a second and the charges induced on the body surface also alternates, i.e., negative charges induced in the upper part of the body at one instant flow into the lower part of the body at the next instance. The power frequency electric field induce currents in the body (eddy current) as well as charges on its surface.

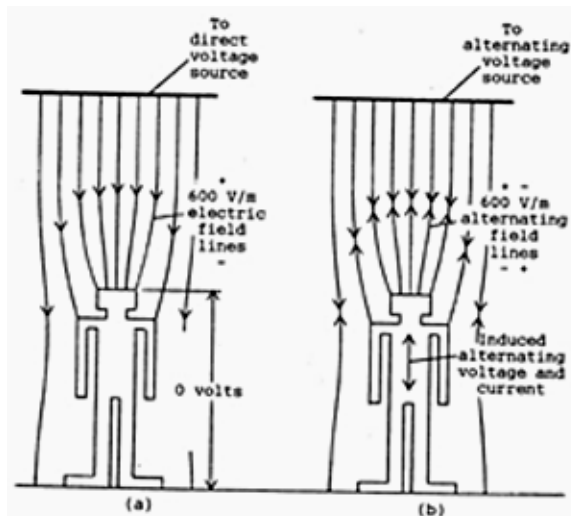


Chart 2: Field lines passing through human body

Magnetic induction: The current induced in the body by magnetic field are greatest near the periphery of the body and smallest at the center of the body.

- Magnetic field induces a voltage in the tissue of human body, which causes a current to flow through it due to its conductivity.

- The magnetic field has the influence on the tissues of the human body, these maybe beneficial or harmful depending upon the nature.
- The magnitude of the surface charge and internal body currents by any given source of power frequency depends upon many factors. For example, this includes magnitude of the currents and charges in the source, the distance of the body from the source, the presence of other objects that might shield or concentrate the field and the body posture, shape, and orientation. For this reason, the surface charges and the currents, which a given field induces are very different for different human beings.
- When a person who is isolated from the ground by some insulating material, comes in close quarters to an overhead transmission line, and electrostatic field is set up in the body of the human being whose ordinary resistance is about 2000Ω . When the same person touches the grounded object, it will discharge through his body causing a large current to flow through the body. Discharge currents from 50Hz electromagnetic field are weaker than natural currents.
- For human beings the limit of the undisturbed field is 15kV/m RMS to experience possible shock.

2.1. SHORT TERM HEALTH PROBLEMS: High power lines emit high levels of electromagnetic radiation. These hazardous man-made EMFs interact in a destructive way with natural electromagnetic fields that exists within human beings. They interfere with cell function, break DNA strands, and erode the immune system. These biological irregularities cause initial symptoms such as dizziness, fatigue, headaches, nausea, and digestive disorders. They often culminate in causing more serious disorders in children, pregnant women, and elderly people.

2.2. LONG TERM HEALTH PROBLEMS: Overhead high voltage power line causes ionization of air emitting trillions of corona ions into the air per second. These ions get attached to the aerosol particles of many types of

carcinogenic air pollution like diesel exhaust, flame retardants in furniture, unintentional by-products of industries, etc. The charged pollution particles are then carried by the wind up to 7kms downwind of the power line and deposit in the lungs at a significantly greater rate than uncharged pollutant particles. The analysis of corona effect risk shows that up to 400 excess cases of lung cancer mortality and 3000 excess cases of cardiovascular and respiratory illness and aggravated asthma may occur annually among 2.7 million people living within overhead high voltage lines. The following is an exhaustive list of negative health outcomes with overhead high voltage power lines exposure over an extended period of time:

- Variety of childhood and adult cancers
- Childhood and adult leukemia
- Alzheimer's disease
- Suicide
- Depression
- Stress
- Specific types of heart disease
- Tumor growth
- Skin growth
- Abnormal cell activity
- Impairment of perception and memory
- Genetic defects
- Gland production deficiency
- Mental and behavioral problems
- Immune system deficiency
- Nervous system disorder
- Birth defects
- Miscarriages
- Stunting of growth
- Fatigue
- Headache
- Nausea
- Decrease in visual and motor reaction time
- Male sexual dysfunction
- Aggravation of asthma
- Sleep deprivation
- Electromagnetic hypersensitivity

Many scientific and medical studies show that higher risks of childhood leukemia are found in children living near overhead lines.

People who live, work or attend school near have increased risk of contracting cancers of different types.

Alzheimer's disease and dementia have been directly linked to exposure of high voltage overhead lines. The risk of Alzheimer's increases to 4.9 times and dementia to 2.5 times the normally expected rate.

3. EFFECT OF ELECTROMAGNETIC FIELD ON ANIMALS

Exposure to high voltage power lines, EMF results in decrease of 5% in milk yield, 13.8% in fat corrected milk yield, and 16.4% in milk fat among the cows. High voltage power lines cause breathing problems and weakened system in cows and pigs. High voltage power lines cause abnormally low pig birth rate, and high piglet mortality, and undersize heifers, and some afflicted with hemorrhages or abortions. Dogs and cats exposed to high EMF levels are still born and deformed puppies and kittens and have abnormal un-breed able seasons, and show risks of lymph cancer 6.8 times the expected rate. Animals kept below high electrostatic field acquires a charge and when they try to drink water, a spark usually jumps from their nose to the grounded pipe. Like hens are unable to pick up grains because of chattering of beaks and it also affects their growth.

4. EFFECT OF ELECTROMAGNETIC FIELD ON PLANTS

The electromagnetic field from high power transmission lines affects the growth of plants in agricultural and forest lands near high power transmission lines. Current in power transmission lines varies according to the load. Hence the effect of EMF due to the current flowing upon the growth of the plants under high power transmission lines remains unaltered throughout the year. From various practical studies, the growth characteristics like shoot length, root length, leaf area, leaf fresh weight, specific leaf weight, shoot/root ratio, total biomass content, total water content of the crop plants were reduced significantly. Similar trends were observed

in the biochemical characteristics like chlorophyll. Reduced growth and physiological parameter was primarily due to the effect of cell division and cell enlargement. Further, there was a stunt in the growth, which is due to poor action of hormones responsible for cell division, and cell enlargement. Conclusively, the biochemical changes produced in the plant due to EMF affects the production leading to economic loss.

5. REDUCTION OF EFFECT OF EMF

- 5.1. LINE SHIELDING: There are two basic 50Hz magnetic field reduction methods, passive and active. Passive magnetic field mitigation reduction includes rigid magnetic shielding with ferromagnetic and highly conducting materials and the use of passive shield wires installed near transmission lines that generate opposing cancellation field from electromagnetic induction. Active magnetic field reduction uses electronic feedback to sense a varying 50Hz magnetic field and generating a proportionally opposing cancellation field within a defined area surrounded by cancellation coils. This technique is successful in both residential and commercial environment to reduce the magnetic fields from overhead transmission and distribution lines.
- 5.2. LINE CONFIGURATION AND COMPACTION: Line compaction brings the conductors close together keeping the minimum safe phase to phase spacing constant. The magnetic field is proportional to the phase to phase spacing. By increasing the distance between phases, by increasing the height of the central phase of the conductor above the level of the other phase conductors, leads to the reduction of the peak value of the magnetic field (as shown in figure below).

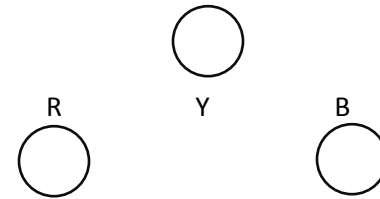


Chart 3: Configuration of lines and compaction

Reducing the phase to phase distance, leads to decrease of the magnetic field. This reduction between the phases is limited by the electrical insulation level between phases. For single circuit lines, and double circuit lines, compaction causes a great reduction in the maximum magnetic field value

- 5.3. GROUNDING: The grounding of metal objects such as fences that are located on the right-of-way (ROW) eliminate these objects as sources of induced current and voltage shocks. Multiple grounding points are used to provide alternative paths for induced current flow and reduce nuisance shocks.
- 5.4. PROVIDING RIGHT-OF-WAY (ROW): overhead transmission system require strips of land which are called right-of-ways. These strips of land are usually evaluated to decrease the effects of energized line.
- 5.5. MAINTAINING PROPER CLEARANCE: Unlike fences or buildings, mobile objects such as vehicles and farm machinery cannot be grounded permanently. Limiting the possibility of induced current from such objects to persons is accomplished by maintaining proper clearances for above ground conductors.

6. CONCLUSION

The research on electromagnetic and different mitigation technique discusses the different equations that allow us to calculate the magnetic fields as well as health effects of the EMF, in general. Values of magnetic fields are obtained by using field work measurement as well as finite element method

simulation using MagNet and MATLAB software for single conductor and three conductors in different configuration as well as for double typical circuit. Further analysis on this topic will help us to completely eradicate the negative effects high voltage transmission lines on the health hazards of human beings and animal life and growth of the plants, which is a challenging feature for young technocrats in future.

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REFERENCES

1. Final Year Project, '*Electromagnetic Field from Power lines*', Abou Iwzeddin Salma, Berbari Kamal, Obeid Hiba, year May 23 2006.
2. Azzuhri 2004, *Power Transmission Line Magnetic Field: A survey on 120kV Overhead Power Transmission lines in Malaysia*, University of Malaysia, Kuala Lumpur.
3. March 2005, *Group Public Position Statement Electric and Magnetic Field*, National Grid.
4. Rashkes. V, *IEEE Transaction on Power Delivery*, Volume 13, No. 2, page 552-559.
5. Electrical Engineering Department at King Fahd University of Petroleum and Minerals by J.M. Bakhawain, M. H. Shwehdi, U. M. Johar, and A. A. AL-Naim.
6. Dept. of Electrical Engineering, College of Engineering, University of Tikrit-Iraq, Ghanim Thiab Hasan, Kamil Jadu Ali, Mahmood Ali Ahmed.
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Impacts of Low Frequency Noise Exposure on Well-Being: A Case-Study From Portugal

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Abstract

Introduction:

The aim of this article is to assess the impacts of low frequency noise, emitted by high-voltage lines and power poles, on the perception of discomfort, comparing two different groups of inhabitants (exposed and unexposed groups) in two areas in the Northwest of Portugal. It proposes a new oriented methodology to assess discomfort due to the low frequency noise.

Materials and Methods:

Two predominantly urban areas were used to test the methodology: an “exposed” area with a high presence of the source under study and an “unexposed” area without records of power transmission lines. The research developed included measuring sound levels (in frequency bands from 10 to 160 Hz) with the help of a sound level meter in the two selected urban areas.

Results:

The real sound coming from the source was recorded and reproduced in an audiometric testing booth to determine the hearing threshold and discomfort of the volunteers. Using the criteria curve developed by DEFRA (Department for Environment, Food & Rural Affairs/University of Salford) in 2011, the results reveal that the sound levels recorded for the “exposed” group were higher than that for the “unexposed” group. The first recording showed an average of 68.9 dB and the second 64.6 dB, resulting in a significant difference of 4.3 dB between the two groups. After an attempt to isolate the source, the difference was 5.6 dB. Regarding the adapted audiometric tests, the real sound was used, which was collected 5 m between the receiver and the source.

Conclusion:

These results provide support that at this distance the noise was considered annoying.

Keywords: audiometric testing, human well-being, noise discomfort, noise pollution, power poles and power lines

INTRODUCTION

There is a relatively large body of literature concerning the impacts on health regarding exposure to environmental noise.^[1,2,3,4,5] However, there are still few studies focusing exclusively on health impacts and discomfort due to low frequency noise. One of the main reasons is low sensitivity of the human auditory system to low frequencies. This type of noise presents very particular characteristics and causes much more discomfort and nonauditory effects in the long term. The range of frequency of low frequency noise is not perfectly clear. Sound up to 250 Hz is sometimes referred to as low-frequency noise.^[6] This research considered sound below 160 Hz as the upper limit of low-frequency. Taking this into consideration, this research aims to help assess noise discomfort by measuring sound levels and comparing them with criterion curves, as well as performing adapted audiometric tests.

Taking this into account, the present research focuses on the impact of exposure to low frequency noise on the perception of discomfort, based on an “exposed” and “unexposed” study conducted between 2013 and 2017 in Serzedelo (southwest of the municipality of Guimarães) and in Abação (São Tomé) (southeast of the same municipality) in the Northwest of Portugal. It focuses on the evaluation of low frequency noise from an area with a large number of power poles and power lines and compares it with another area where there is no concentration of this type of elements. The noise emitted from high-voltage lines is caused by the discharge of

energy that occurs when the electrical field strength on the conductor surface is greater than the “breakdown strength” of the air surrounding the conductor. The degree or intensity of the corona discharge and the resulting audible noise are affected by the air condition (e.g., humidity, wind and water, drizzle, and fog).[2]

In the present study, due to inconsistencies in the available data, the weather conditions were not considered. Weather data were collected from the nearest automatic weather station. Due to maintenance problems, this station did not have data on the velocity and direction of wind. On the other hand, given the location of the weather station (located more than 7 km from the areas under analysis), the data were not considered representative.

The sound levels were measured from 2014 to 2015 and compared with a criterion curve from a methodology developed by DEFRA (Department for Environment, Food & Rural Affairs/University of Salford), created in 2011[8] and tested in some studies[1,2,3] to analyze the discomfort in the population, resulting from the indoor annoyance of low-frequency noise.

In a survey conducted in 2015, from the 1022 dwellings located in the village of Serzedelo, only 98 are 250 m (or more) away from high-voltage lines, that is, 9.6% are very close to these elements (up to 250 m).[1] This causes a conflict regarding the use of space. The study presented here follows the conclusions found in the previous approach,[1] where according to the DEFRA methodology, noise data were collected inside dwellings. To increase the sample, it was decided to make a large number of measurements outside the dwellings, for shorter representative periods, guaranteeing a greater spatial coverage. An analysis was made of the “exposed” and “unexposed” groups. Thus, two similar territories were used: one having high-voltage lines; and the other in the same municipality without this type of elements. In addition, in 2016 and 2017, audiometric tests adapted to the low frequencies were conducted with the “exposed” and “unexposed” volunteers to determine the hearing threshold for pure sounds and for the real sound recorded.

The investigation attempts to answer the following questions: (a) Do power poles and power lines cause noise? (b) Do power poles and power lines cause discomfort due to noise? and (c) Is it suitable to use the A-weighting filter to analyze discomfort due to the noise from power poles and power lines?

This research is part of a broader research project developed by a team of researchers from the University of Minho, who are evaluating the impact of low-frequency noise pollution on the health and well-being of the population.[1] The results found by this team of researchers, obtained only in the village of Serzedelo, showed that regardless of the distance from the source, “near the source” (up to 50 m) and “away from the source” (more than 250 m), the noise levels exceeded the reference values of the methodology developed by DEFRA.[8] According to these authors, two possible explanations may be presented to explain this result. First, the low-frequency noise measured for the “away from the source” group may come from other sources. Second, the need to redefine group limits, that is, what is being considered as “away from the source” may be classified as “near the source.” The authors recommend choosing a territory where individuals are not under the influence of power poles and power lines and other sources of low-frequency noise emission.[1]

Exposure to low frequency noise and the impacts on human health

Many studies have shown the relationship between noise and the development of cardiovascular diseases,[9,10,11,12,13] agitation and distraction[14,15,16,17] and sleep disturbance.[4,5,18]

Emotional changes have also been documented: agitation, distraction, disappointment and psychological disorders, such as depression, stress, and irritability.[14,15,16,17,19,20]

Concerning “nonauditory effects,” discomfort has been reported as the most frequent impact of exposure to low frequency noise in humans.[6,17,21,22]

Different from “auditory effects,” “nonauditory effects” are the most difficult to prove as they result exclusively from exposure to noise. Assessing noise discomfort is generally centered on medium and high frequencies.[1,22]

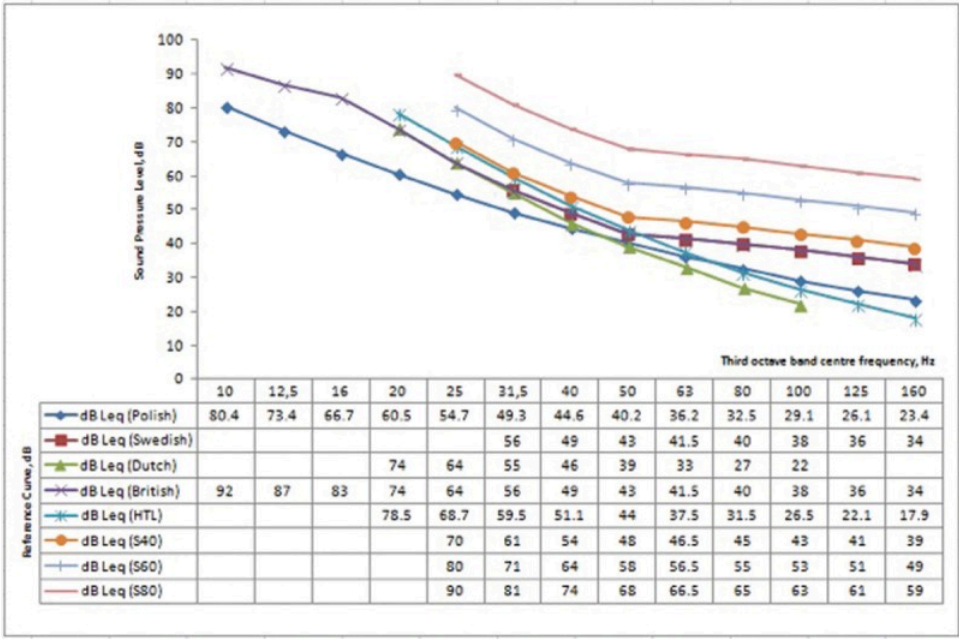
By convention, a frequency A-weighting filter is used in these evaluations because the human auditory system is not very sensitive to low frequencies. However, is an A-weighting filter more suitable to assess discomfort due to low-frequency noise? Some studies indicate that the A-weighting filter is not suitable for assessing the discomfort of low-frequency noise.[21,22,23,24] In the authors’ opinion, this evaluation should be made using an appropriate filter or in linear mode.

Methodologies for assessing discomfort due to low frequency noise

Some guidelines for low frequency noise control in residential areas, adopted in some European countries such as Germany and the United Kingdom,[8,25] are based on a 1/3 octave analysis of sound pressure levels (SPLs) measured and compared with criterion curves. However, in the case of some methods, corrections are applied, such as the A-weighting filter.

Using this filter leads to a significant reduction in the sound levels emitted, often contributing to the resulting values remaining below the levels considered as annoying or harmful, when compared with criterion curves used in various countries [Figure 1].

Figure 1.



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Criterion curves used for the assessment of discomfort due to exposure to low-frequency noise, according to the various existing methods[1,3,4,21]

Figure 1 presents reference curves used in various criterion concerning environmental exposure (at dwellings) and Swedish recommendations for workplaces.

It can be observed that the existing methods are based on quantitative parameters to analyze discomfort due to low frequency noise, while discomfort is essentially a subjective parameter, which can vary from individual to individual. These methods consider a limited frequency range, and generally span the frequency range between 25 and 200 Hz.

The current legislation for ambient noise adopted in Portugal, which falls within the scope of the NP ISO 1996 standard, establishes that noise assessment should use frequency A-weighting, with fast integration time and frequency bands of 1/3 octave to vary between 50 and 10,000 Hz.[26,27]

In the study of discomfort due to low-frequency noise, there is a need to lower the minimum threshold of assessment, that is, below 50 Hz. In this respect, the methodology developed by DEFRA in 2011 is worth mentioning as it covers a broad frequency range from 10 to 160 Hz and also because it recommends conducting surveys as a complement to analyzing noise discomfort.

MATERIAL AND METHODS

This research comprises an “exposed” and “unexposed” study, conducted in two predominantly urban areas of the municipality of Guimarães. The “exposed” area was defined due to a high presence of power poles and power lines. Considering this, the village of Serzedelo was selected, whose area has more than 80% of this type of infrastructure and which includes in its vicinity a substation with the highest installed power at national level called Riba d’Ave Substation[1] and the choice of territory free of the passage of these infrastructures and without the presence of other sources of emission of low-frequency noise. Considering these aspects, the village of Abação (São Tomé) was chosen, classified as “unexposed.”

The adopted methodology was divided into two dimensions performed in the “exposed” and “unexposed” groups. The objective dimension included measuring noise levels in 2015 and comparing them with the criterion curve of the DEFRA methodology.[8] The subjective and complementary dimension focusing on the audiometric tests adapted to low frequencies was conducted with the volunteers in 2016 and 2017.

Methodology developed by DEFRA (NANR45)

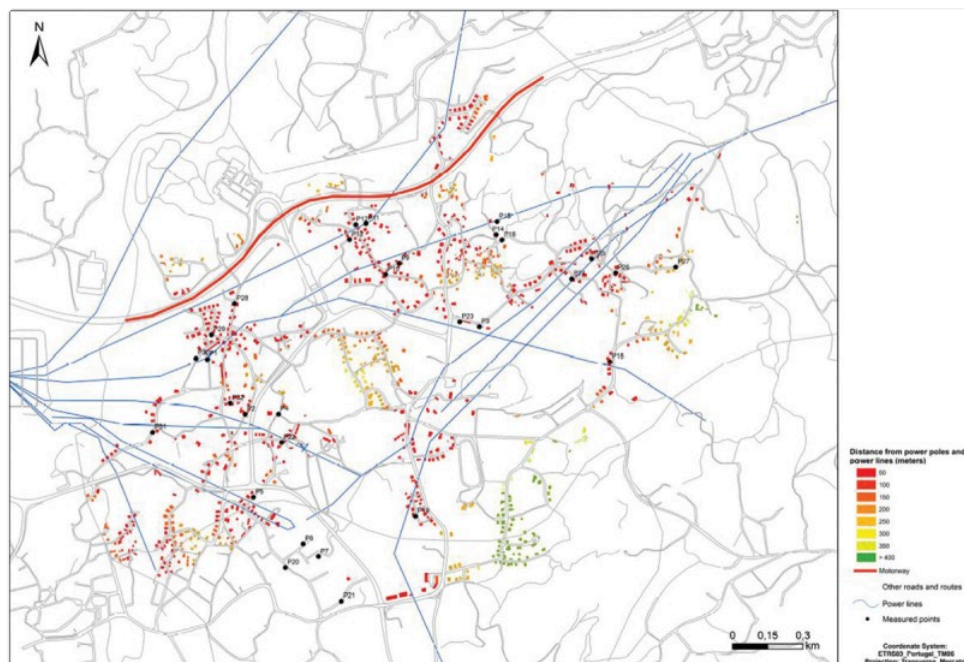
Among the various methods to analyze the discomfort due to low frequency noise is a procedure developed by the DEFRA Acoustics Research Center at the University of Salford called proposed criteria for the assessment of low frequency noise disturbance (NANR45).[8] The procedure proposes the measurement of noise levels for 72 h (3 days) and comprises the night time, from 02:00 to 04:00, in 1/3 octave bands from 10 to 160 Hz. The measured values in L_{eq} are compared

with a criterion curve, which corresponds to a threshold of discomfort per frequency band. If the L_{eq} values exceed the reference values, it is an indication that the noise source may cause discomfort.[8] Additionally, according to the DEFRA methodology,[2] when the $L_{10}-L_{90}$ difference exceeds 4 dB, the sound fluctuates and a penalty should be imposed. This methodology suggests that 5 dB relaxation may be applied for steady sounds, rather than introducing a penalty for fluctuating sounds. Furthermore, it states that a fluctuating sound with an average level of 5 dB below the threshold would be audible, whereas a steady sound would not. Because the curve values at low-frequency are set at 5 dB below the threshold, this is again consistent with allowing relaxation for steady sounds.[1,8]

Assessment of noise levels

Considering the results obtained in Alves *et al.*,[1] it was decided to adapt the DEFRA methodology, that is, to take a larger number of measurements for representative, but shorter periods of 15 min each and measured outside the housing. Taking this into account, a greater spatial coverage was guaranteed at several points located in the two selected areas. Therefore, in the village of the “exposed” group, 32 measurements were performed [Figure 2] in November, 2015 (autumn).

Figure 2.

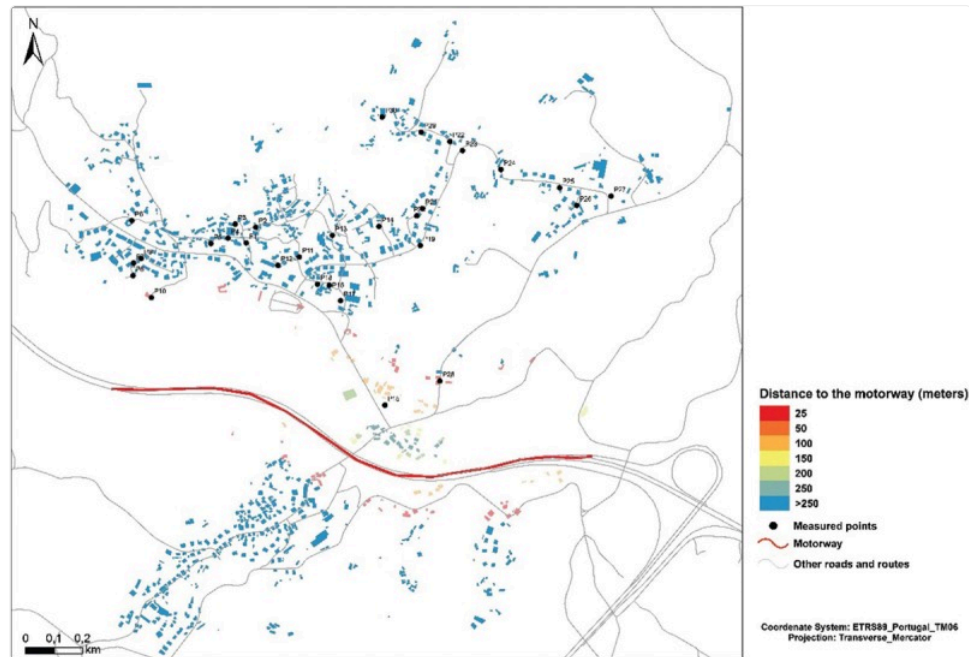


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Location of the measured points in the village of the “exposed” group in relation to the distance from the power poles and power lines

In the village of the “unexposed” group, 30 measurements were performed in December, 2015 (autumn) [Figure 3].

Figure 3.



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Location of measured points in the village of the “unexposed” group in relation to the distance from the motorway

The sound levels in L_{eq} (dB) were measured and compared with the values of the criterion curve proposed by the DEFRA methodology.[8] A sound level meter class 1 was used with third octave filters from 10 to 160 Hz, a tripod and a field calibrator. The height of the measurements was 1.2 m, and it was measured at a distance more than 4 m away from the nearest facade. The fluctuating characteristics of the noise were evaluated by calculating the difference between L_{10} and L_{90} to evaluate the discomfort due to this type of noise.

It is important to refer the complexity of the analysis in this type of investigation due, among other aspects, to the interference from sources other than the source under study, such as road traffic (heavy vehicles). For this reason, it was decided to make an isolated analysis of a set of points without road traffic interference, mainly of the heavy vehicles.

Discomfort analysis using adapted audiometric tests to the low frequencies – methodological proposal

The audiometric tests were taken as a complement of analysis for the measurements performed *in loco* and comprised the perception of the discomfort due to noise, orienting exclusively for the low frequencies. It was observed that, although the noise was perceptible, the “exposed” individuals seemed to be accustomed to it.[1] Considering this, the audiometric tests were used to remove individuals from their habitual place of residence and to introduce, within the audiometric booth, the same acoustic stimulus to which they are exposed to in their daily lives.

It should be noted that in the literature on the subject, there is no methodology for audiometric evaluation oriented to low frequencies and, due to this aspect, the protocols developed were adapted based on ISO 8253-1/2010,[28] which can be confirmed in the Supplementary Material of this paper.

The tests consisted of three stages: the hearing threshold, the assessment of discomfort due to noise and the cognitive test performance [mini mental state examination (MMSE)].[22] The test procedure has a duration of approximately 25 min.

Due to limitations of the audiometer, not allowing them to operate with the desired frequencies (below 50 Hz), it was decided to use the VLC media player in the computer to reproduce the sound source. The audiometer was used only to vary the intensity of the signal. Thus, the following circuit was established: computer – audiometer – audiometric booth.

To determine the hearing threshold of pure sound, it was reproduced by frequency bands, from 18 to 90 Hz (18 Hz; 21 Hz; 24 Hz; 30 Hz; 39 Hz; 51 Hz; 60 Hz; 80 Hz; 90 Hz) with a variation in the signal intensity. The hearing threshold was also determined for the recorded sound composed from the real sound, with varying signal intensity. The hearing threshold was also determined for the recorded sound (real sound) with varying signal intensity. The real sound was recorded at 5 m from the projected horizontal distance from the nearest source (power pole 400 kV). The characteristics of the recorded sound are listed in [Table 1](#).

Table 1.

Characteristics of the recorded sound – exposed area

Group	Proximity of the source (m)	L_{eq} (dB)	L_{min} (dB)	L_{max} (dB)	Exceeded range (Hz)	Environmental area
“Exposed”	5	54.5	48.4	62.9	25–160	Located near the high voltage power pole (400 kV). Weather conditions: humid, cloudy and rainy. Sound recording lasted 15 min (between 2:15 PM and 2:31 PM)

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The recorded sound (real sound) is variable, consisting of background noise from different and varied sources in addition to the main source. The hearing threshold was evaluated in the total frequency of the real sound. For this reason, the participant’s response to the signal was considered, and the values reported in more than 50% of the responses were determined as the hearing threshold.

The participants, after being exposed to the reproduction of pure sounds and recorded sounds, responded to a small three-question survey.

The subjective and complementary dimension to determine the hearing threshold consisted of conducting a small discomfort survey (using a Likert scale)[22] before exposure to noise in the audiometric booth, as well as doing a cognitive test,[29] performed after the audiometric tests.

The tests were conducted in an audiometric booth Optac – Aumec Horprufkabine brand, and two acoustic stimuli were introduced: pure sounds (tracks from a high-fidelity CD of the brand Nordost – System Set-Up & Tuning Disc) and the sounds previously recorded at the place of exposure.

The sound was reproduced inside the audiometric booth through headphones with good response at low frequencies of the model (HE400S – Hifiman).[30] Connections were made to allow the passage and control of the signal by the AD28–Interacoustics audiometer.

The pure sounds were played by Windows Media Player, and the recorded sound was played by software dBTrait.[31]

According to the mentioned methodology, audiometric tests were performed with eight volunteers from the “exposed” group and six volunteers from the “unexposed” group. It is important to highlight the difficulty of recruiting volunteers to participate in the audiometric tests, because the audiometric booth used is in the Laboratory of Ergonomics at the University of Minho. In fact, after several attempts by telephone, and even when the team offered transport to the individuals invited to participate in the audiometric tests, few accepted to participate.

MAIN RESULTS

In this section, we describe the results of the sound levels measured in the two predominantly urban areas, as well as the results obtained with the performance of the adapted audiometric tests.

The measured sound levels

For both the “exposed” and “unexposed” groups, the measured sound levels ($n = 62$) exceeded the reference values when compared to the DEFRA criterion curve in different bands of frequency. The mean exceeded recorded was obtained by averaging the values of pressure sound levels obtained at each measurement point. For the “exposed” group, it was 68.9 dB, and for the “unexposed” group it was 64.6 dB. The difference of the average of exceedance was of 4.3 dB, which reveals a considerable difference between the two evaluated situations.

Another aspect that deserves attention is related to the percentage of time in which fluctuating characteristics were registered. In fact, in $L_{10}-L_{90} \geq 4$, for the “unexposed” group, the occurrence frequencies tended to be lower than those recorded for the “exposed” group.

The exceeded SPL, referred to in Tables 2 and 3, corresponded to the sum of the noise exceedances in relation to the DEFRA curve criteria of the exceeded frequency bands.

Table 2.

Characteristics of measurement points of the “exposed” group – sound levels with interference reduction

Point	Proximity to the source (m)	Exceeded		Environmental area
		Range (Hz)	SPL (dB)	
1	1	40–160	+63.8	Predominantly soil: unpaved ground. Located near the high voltage power pole (400 kV)
3	10	31.5–160	+104.7	Predominantly soil between sound level meter and the source: granite cube. Passage of vehicles during measurement: one heavy vehicle and 11 light vehicles
5	25–50	31.5–160	+121.4	Predominantly soil: granite cube. Passage of vehicles: two light vehicles. About 10 km away from the Riba d'Ave Substation
7	5	50–160	+21.4	Predominant soil: granite cube. Passage of vehicles: one heavy vehicle. Located near the urban gardens with power poles and power lines. Noise perceived: continuous noise from the power pole
8	5	31.5–160	+36.7	Predominantly soil: unpaved ground. Predominant soil: granite cube. The noise of the power pole and power line is highway perceptible
9	5	40–160	+39.2	Predominantly soil: asphalt pavement. Located near the urban garden. Passage of one heavy vehicle
10	10	40–160	+32.3	Predominantly soil: asphalt pavement. Passage of two light vehicles. Noise perceived: continuous noise from the power pole
11	8	40–125	+37.4	Predominantly soil: grassy. Noise perceived: continuous noise from the power pole and road traffic
12	50–75	50–160	+39.8	Predominantly soil: grassy and asphalt pavement. Passage of vehicles: one light vehicle and one heavy vehicle
13	10	40–160	+71.3	Predominantly soil: asphalt. Noise perceived: continuous noise from the road traffic. Passage of vehicles: one light vehicle
14	10	50–160	+33.6	Predominantly soil: granite cube. Noise perceived: continuous noise from the power pole and road traffic
15	20	50–160	+13.7	Predominantly soil: unpaved ground. Passage of vehicles: one light vehicle. Reports: noise discomfort from the power pole and some health problems. Noise perceived: continuous noise from the power pole
16	50–75	50–160	+16.5	Predominantly soil: unpaved ground. Nearest highway pavement: granite cube. Located near the urban gardens with power poles and power lines. Noise perceived: continuous noise from the power pole
17	8	50–160	+28.3	Predominantly soil: granite cube. High density of 150 kV voltage power poles and power lines
19	50	40–160	+45.4	High density of 150 and 400 kV voltage power poles and power lines. Predominantly soil: granite cube
20	10	40–160	+49.3	Predominantly soil: granite cube. Noise perceived: continuous noise from the power pole. Passage of vehicles: one light vehicle
21	20	40–160	+87	The receiver was positioned 12 m away from the façade of a textile industry in the village. Passage of vehicles: one light vehicle
22	30	31.5–160	+109.5	Predominantly soil: granite cube. Passage of vehicles: three light vehicles and two heavy vehicles. Located near extensive cultivation areas (urban garden)
24	10	40–63 and 125–160	+9.5	Predominantly soil: granite cube. High density of power poles and power lines
25	10	50–160	+31	Predominantly soil: granite cube. High density of power poles and power lines. Presence of boulders
26	5	31.5–160	+103	Predominantly soil: granite cube. Passage of vehicle: one light vehicle. Noise perceived: continuous noise from road traffic

Point	Proximity to the source (m)	Exceeded		Environmental area
		Range (Hz)	SPL (dB)	
27	50	50–160	+33.7	Predominantly soil: granite cube. Passage of vehicle: one light vehicle. Noise perceived: continuous noise from road traffic
28	50	40–160	+81.6	Surrounded by vegetation. Noise perceived: continuous noise from power poles and power lines and noise from road traffic
29	25	31.5–160	+87.8	Predominantly soil: granite cube. High density of power poles and power lines. Passage of vehicles: five light vehicles
30	50	40–160	+50.7	Predominantly soil: unpaved ground and vegetation. Passage of one light vehicle. Located near the Riba d'Ave Substation
32	1	31.5–160	62.7	Predominantly soil: grassy. Noise perceived: continuous noise from power poles and power lines and noise from road traffic

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Table 3.

Characteristics of measuring points of the “unexposed” group – sound levels with interference reduction

Point	Exceeded		Environmental area
	Range (Hz)	SPL (dB)	
2	50–160	+23.5	Predominantly soil: granite cube. Noise perceived: continuous noise from road traffic
3	40–160	+89.4	Predominantly soil: granite cube. Noise perceived: continuous noise from road traffic
4	40–160	+74.7	Predominantly soil: asphalt. Passage of vehicles: one light and one heavy vehicle
5	31.5–160	+89.8	Predominantly soil: granite cube. Noise perceived: continuous noise from road traffic. Passage of vehicles: one light and one heavy vehicle. Located near extensive cultivation areas (urban garden)
6	40–160	+49.9	Predominantly soil: granite cube. Noise perceived: continuous noise from road traffic.
8	40–160	+50.4	Predominantly soil: granite cube. Passage of one light vehicle. Noise perceived: continuous noise from road traffic (about 25 m from the measurement point)
9	50–160	+16.7	Predominantly soil: granite cube. Noise perceived: continuous noise from road traffic. Located near the houses and extensive cultivation areas (urban garden)
10	50–160	+25.2	Noise perceived: continuous noise from road traffic. Predominantly soil: granite cube. Located near the extensive cultivation areas
11	50–160	+27.2	Receiver positioned on the granite cube pavement, approximately 3 m from the asphalt road. Located near the residential area. Noise perceived: continuous noise from road traffic
12	40–160	+21.5	Predominantly soil: granite cube. Passage of one light vehicle. Located near the houses and the primary school
13	31.5–160	+82.4	Predominantly soil: granite cube (the receiver was positioned on the unpaved ground). Noise perceived: noise from road traffic (José Manuel Street)
14	50–160	+31.4	The receiver was positioned on the concrete pavement. Located near the asphalt residential area
15	40–160	+49.2	Predominantly soil: granite cube. Noise perceived: noise from the road traffic
16	40–160	+51.4	Predominantly soil: asphalt. Passage of one light vehicle. Located near the residential area and urban gardens. Noise perceived: noise from road traffic (São Tomé Street)
18	40–160	+51.8	Noise perceived: noise from road traffic
20	50–80 and 160	+12.4	Predominantly soil: granite cube and vegetation. Noise perceived from road traffic
23	40–160	+68.9	Passage of six light vehicles and one heavy vehicle. Located near urban gardens. Note: measurement performed without the microphone sponge
24	40–160	+78.9	Located near urban gardens. Predominantly soil: asphalt
26	40–160	+32.7	Predominantly soil: asphalt. Located near the Vaga Bond industry and the residential area
29	40–160	+48.7	Predominantly soil: asphalt and granite cube. Passage of three light vehicles and one heavy vehicle. Noise perceived from road traffic
30	50–160	+57.6	Predominantly soil: asphalt. Passage of one light vehicle. Located near the industry and residential area. Receiver positioned on the granite cube pavement

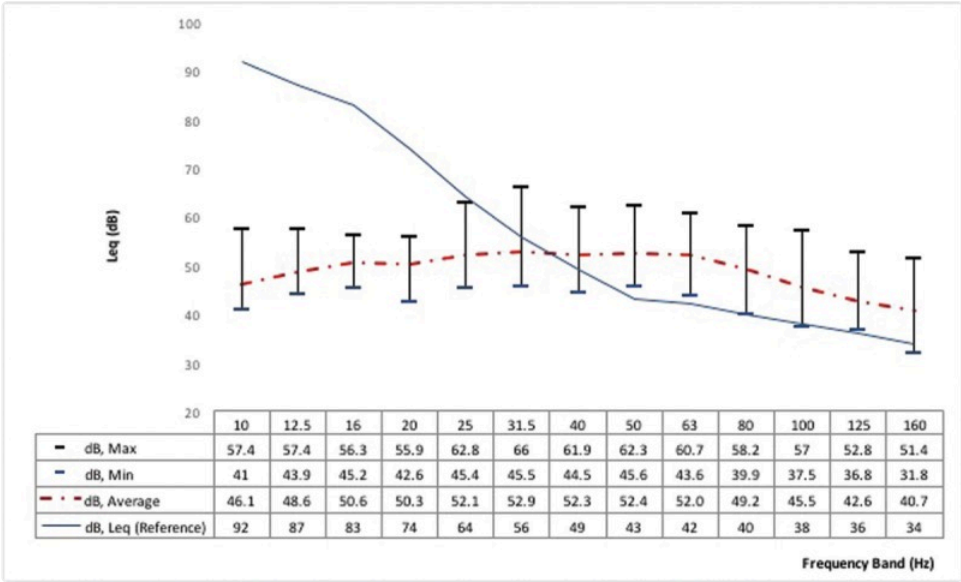
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Isolated approach without road traffic interference

Sound levels – “exposed” group

For this group, 26 points ($n = 32$) were isolated with none or negligible register in terms of road traffic interference (mainly of heavy vehicles), measured in the exposed area [Figure 4].

Figure 4.



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Isolated analysis of the “exposed” group sound levels – analysis in L_{eq} (dB)

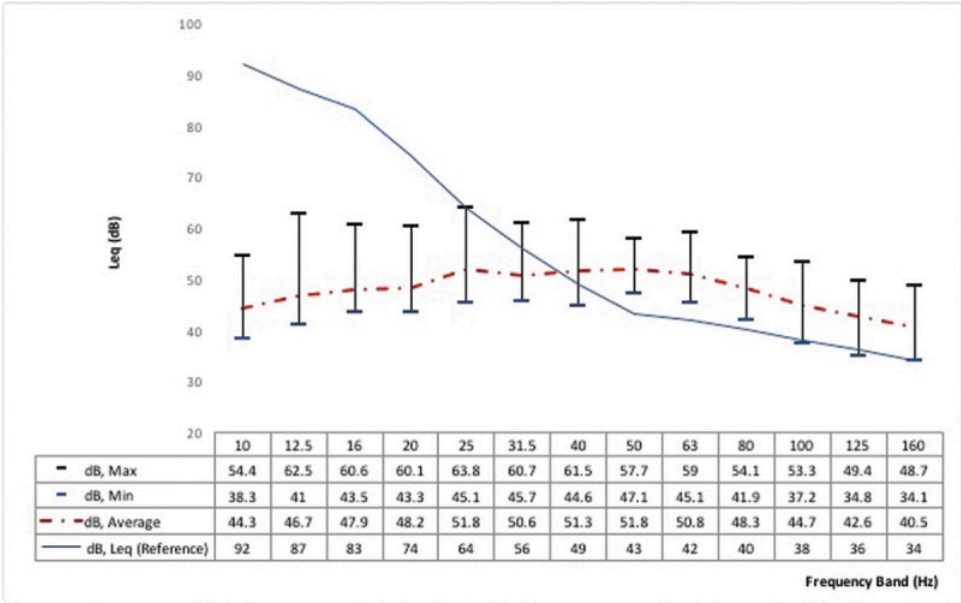
The “exposed” group, without interference from road sources, exceeded for all points measured between the bands of 50 and 160 Hz. The mean exceeded recorded in this group was 55.7 dB [Figure 4 and Table 2].

Higher noise levels could be justified due to the distance from the source (near and very close to the source), the presence of high power poles and power lines (e.g., 400 kV) and the nearby space characteristics, which can potentiate sound levels at very low frequencies.

Sound levels – “unexposed” group

For this group, 21 points ($n = 30$) were isolated with no or negligible interference from car traffic (mainly from heavy vehicles) [Figure 5 and Table 3].

Figure 5.



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Isolated analysis of the “unexposed” group sound levels – analysis in L_{eq} (dB)

The “unexposed” group exceeded for all measurement points between 50 and 80 Hz bands. The mean exceeded recorded in this group was 50.1 dB [Figure 5].

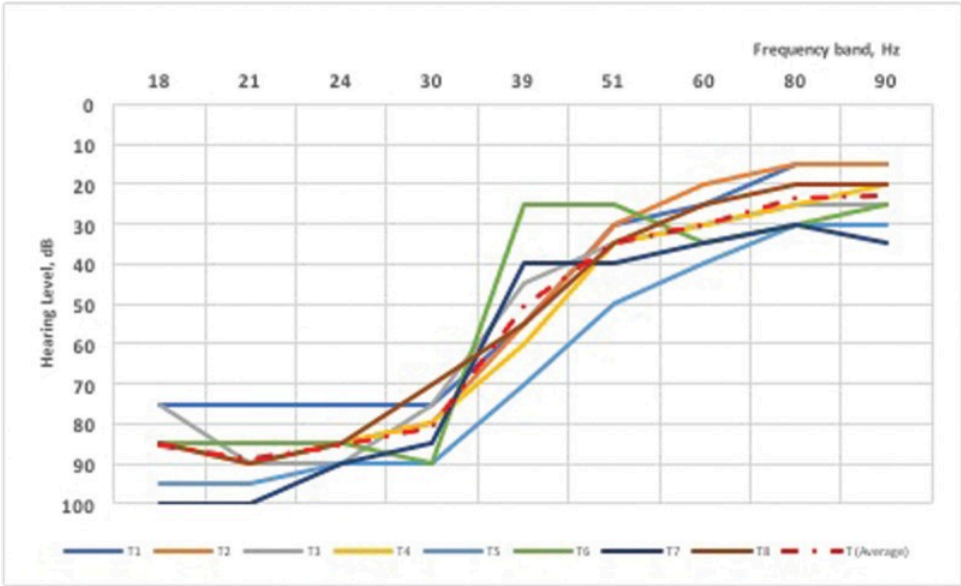
The sound levels could be justified due to surrounding space characteristics (e.g., cultivated areas), influence of other sources and climatic conditions, which may have influenced the sound levels measured, especially at low frequencies.

Audiometric tests and discomfort evaluation due to the low frequency noise (LFN)

Audiometric tests were performed with eight volunteers from the “exposed” group aged between 24 and 68 years, with a distinct professional profile (students, various occupations in the textile industry and an administrative assistant). In the “unexposed” group, audiometric tests were performed with six volunteers, aged between 44 and 60 years and a differentiated occupational profile (unemployed, drivers and construction workers).

Regarding pure sounds, in both the “exposed” [Figure 6 and Table 4] and “unexposed” groups [Figure 7 and Table 4] in all the frequency bands, the hearing threshold was evaluated and presented different sonorous intensities, varying from individual to individual.

Figure 6.



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Hearing threshold for pure sounds from “exposed” group

Table 4.

Hearing threshold for pure sound from “exposed” and “unexposed” groups

Group	Hearing threshold (dB)	18	21	24	30	39	51	60	80	90
“Exposed”	Minimum	75.0	75.0	75.0	75.0	25.0	25.0	20.0	15.0	15.0
	Maximum	100.0	100.0	90.0	90.0	55.0	50.0	35.0	30.0	35.0
	Average	85.6	88.7	85.6	80.6	50.6	35.0	30.0	23.7	23.1
“Unexposed”	Minimum	45.0	40.0	40.0	35.0	20.0	25.0	20.0	20.0	15.0
	Maximum	65.0	60.0	60.0	55.0	50.0	45.0	40.0	35.0	30.0
	Average	51.7	47.5	46.7	40.0	34.2	30.0	27.5	25.0	21.7
Δ “exposed” and “unexposed”		33.9	41.2	38.9	40.6	16.4	5.0	2.5	-1.3	1.4

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Figure 7.



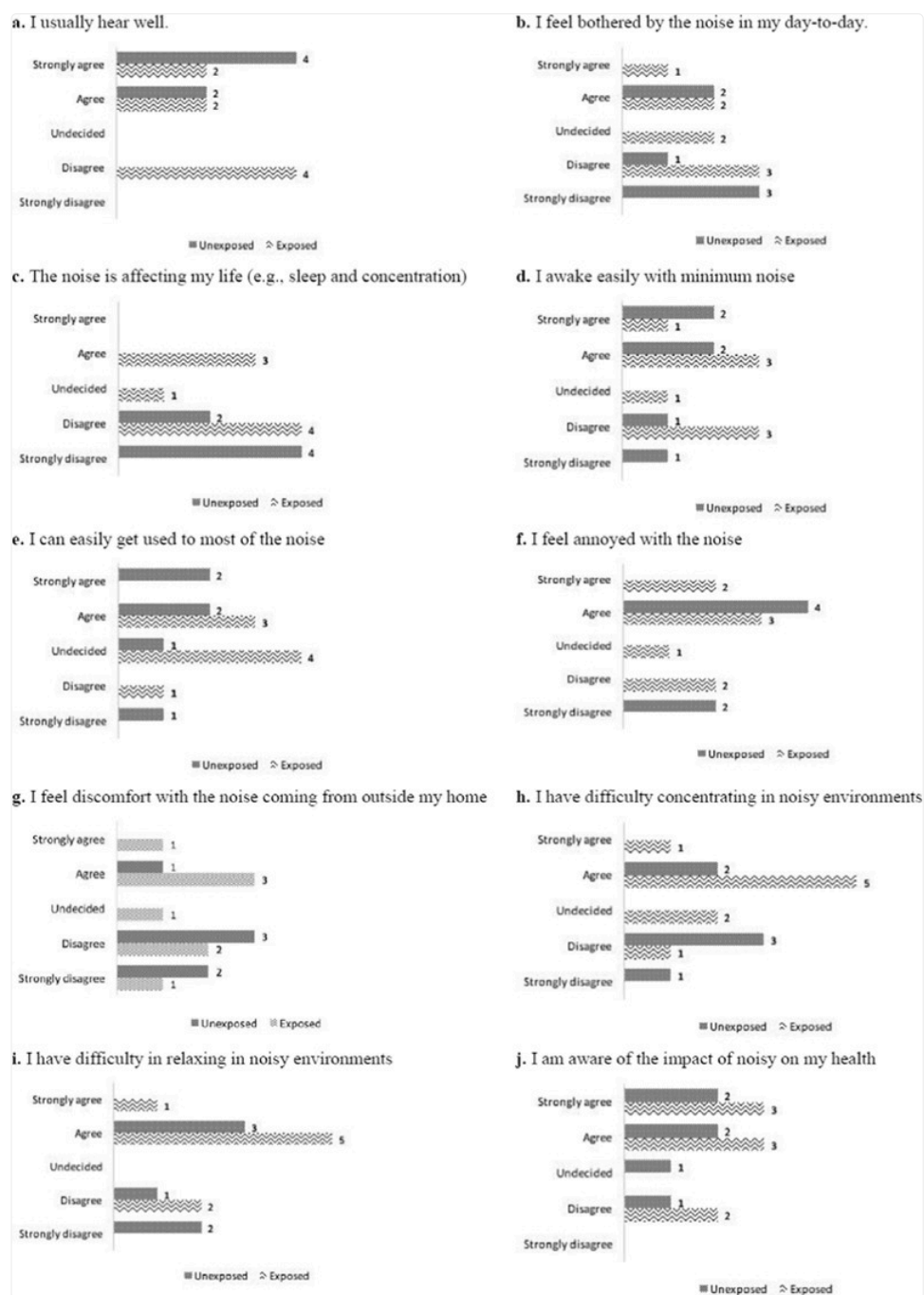
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Hearing threshold for pure sounds from “exposed” group

The average hearing threshold of the recorded sound of the eight volunteers tested from the “exposed” group was 51.3 dB, ranging from 40 to 65 dB, while the average hearing threshold of the six volunteers tested from the “unexposed” group was 24.1 dB, ranging from 20 to 30 dB.

The perception of discomfort due to noise was assessed using a survey (with 10 questions) with a five-level Likert scale, ranging from “strongly disagree” to “strongly agree” [Figure 8a–j].

Figure 8.

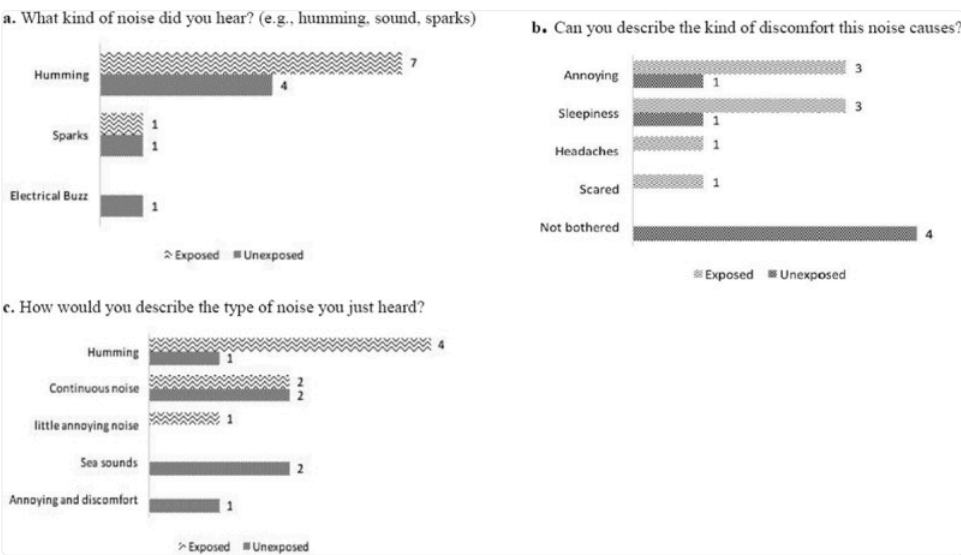


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Evaluation of the perception of discomfort due to noise for the “exposed” and “unexposed” groups

“Exposed” and “unexposed” volunteers answered three questions to assess the perception of the noise reproduction within the audiometric booth [Figure 9a–c].

Figure 9.



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Evaluation of real sound recorded reproduced in the audiometric booth of the “exposed” and “unexposed” groups

In the case of the “unexposed” group, for most participants (67%), the noise reproduced within the audiometric booth corresponds to a “humming” noise. Volunteers typified the noise in some differentiated types as “continuous noise,” “sea waves,” and, finally “annoying and discomfort.” Regarding “discomfort,” four participants responded, “not bothered,” one respondent felt “sleepiness,” and another volunteer felt “annoyed.”

After exposition inside the audiometric booth, the MMSE was conducted to evaluate the cognitive status of the volunteers. The procedure involved two categories of response: verbal and nonverbal.

The first category measured the spatial-temporal orientation, immediate memory, evocation, and memory of procedure, attention, and language. The second category, nonverbal, was responsible for measuring perceptual-motor coordination and comprehension of instructions. The maximum score of MMSE is 30 points, and the interpretation of the test results is shown in [Table 5](#).

Table 5.

Interpretation of results of the mini mental state examination

30–26 points	26–24 points	23 points or less
Preserved cognitive function	Nonsuggestive change in deficit	Cognitive deficit

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Data source: Adapted from Agência Portuguesa do Ambiente.[\[27\]](#)

Tables [6](#) and [7](#) present social and educational characteristics of the volunteers and the score reached by each one during the cognitive tests.

Table 6.

Profile of volunteers from the “exposed” group

Test	Age (years)	Sex	Occupation	Time	Previous occupation	Time (years)	Education	Score MMSE
1	24	M	Student	Since always	–	–	Master	27
2	56	M	Unemployed	6 months	Textile operator	45	Year 9	27
3	58	M	Weaving	42 years	–	–	Year 4	25
4	62	M	Unemployed	6 months	Garage manager	16	Year 4	26
5	68	M	Retired	13 years	Textile carder	44	Year 4	22
6	49	M	Administrative assistant	26 years	–	–	University degree	26
7	63	M	Retired	4 years	Textile Stamper	44	Year 3	26
8	50	M	Operations assistant	26 years	Textile operator	26	Year 11	27

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Table 7.

Profile of volunteers from the “unexposed” group

Test	Age (years)	Sex	Occupation	Time	Previous occupation	Time (years)	Education	Score MMSE
1	45	M	Construction workers	9 years	Locksmith	15	Year 4	29
2	44	M	Unemployed	10 years	Construction workers	5	Year 2	17
3	49	M	Unemployed	10 years	Textile	20	Year 6	30
4	60	F	Housewife	Since always	Textile (operator)	22	Year 4	26
5	45	M	Driver	10 years	Textile (operator)	10	Year 9	26
6	47	M	Driver	7 years	Automotive electrician	20	Year 9	29

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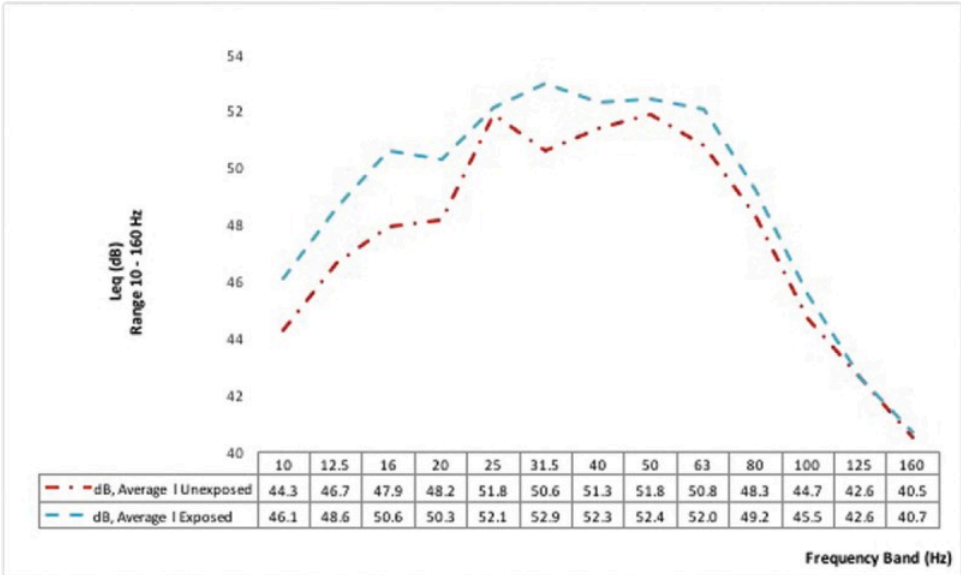
DISCUSSION

Objective dimension – measured sound levels

Regardless of the group analyzed (“exposed” and “unexposed”), the recorded sound levels exceeded the criterion curve of the DEFRA, having been registered for the points measured in the group of “exposed” higher sound levels. One of the possible explanations for this exceeded value could be the contribution of noise not only from the source under study, but also from other sources with low-frequency characteristics, such as road traffic noise (heavy vehicles). Due to the above-mentioned interferences, the isolated sound level analysis was performed, which included the study of a set of points that did not register the passage of heavy vehicles.

After source isolation, with the minimization of interference due to heavy traffic, the average of the “unexposed” group exceeded 50.1 dB, while the average of the “exposed” group was 55.7 dB. Under these conditions, it was found that the low-frequency sound levels recorded for the “exposed” group were higher than for the “unexposed.” This means that if the studied source is the predominant contribution to measured low frequency noise, the “exposed” source more than doubles in comparison with the “unexposed” one [Figure 10].

Figure 10.



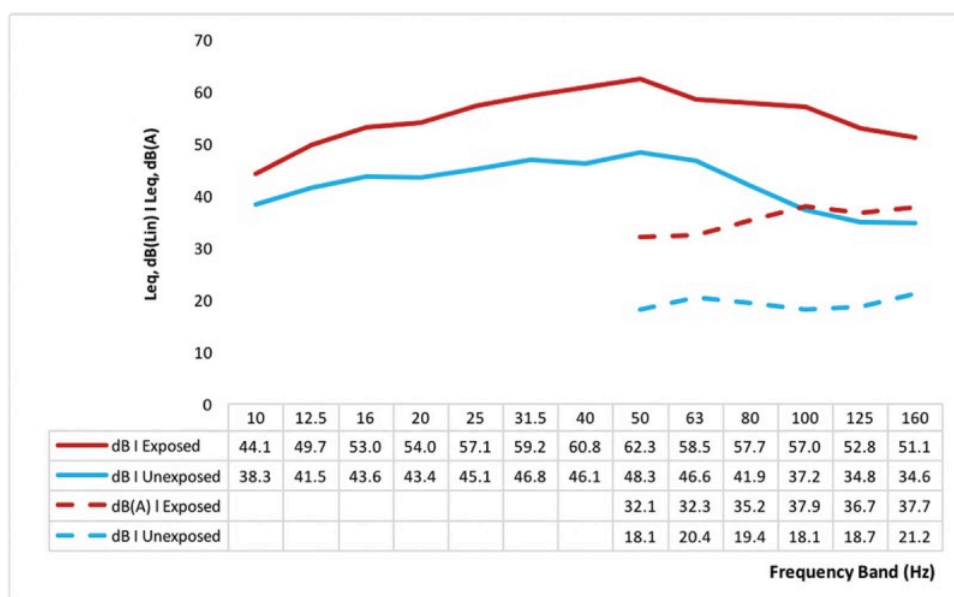
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Isolated analysis of the “exposed” and the “unexposed” group sound levels – dB, average

Considering this, the increase of 5.6 dB can be considered significant. In this analysis, we can say that the village of the “exposed” presented, on average, higher levels due to the presence of power poles and power lines that occupy more than 80% of the area of this village. Taking this into account, the study source played an important role in the recorded sound levels.

The A-weighting filter was applied, having as a reference point 5 (Table 2–“exposed” group), which recorded the highest noise levels and point 20 (Table 3–“unexposed” group), which recorded the lowest noise levels. As illustrated in Figure 11, using the A-weighting filter considerably penalizes the sound levels measured and disguises the objective parameters of evaluating discomfort due to low frequency noise.

Figure 11.



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Isolated analysis of the “exposed” (point 5) and the “unexposed” (point 20) group sound levels – L_{eq} , dB(Lin) and L_{eq} , dB(A)

Based on Portuguese legislation on ambient noise (DL 9/2007), 50 Hz was considered the minimum limit of evaluation, for this reason the A-weighting filter was applied only between frequencies from 50 to 160 Hz [\[Figure 11\]](#).

Subjective dimension – adapted audiometric tests

The registered differences in the hearing threshold for the “exposed” and “unexposed” groups, for pure sounds and real sound recorded (in locals without interference from other sources of noise) were significant [\[Table 4\]](#).

Concerning pure sound, the differences between the averages of the hearing threshold were 33.9 dB for the 18 Hz; 41.2 dB for the frequency of 21 Hz; 38.9 dB for the 24 Hz frequency; 40.6 dB for 30 Hz; 16.4 dB for the frequency of 39 Hz; 5.0 dB for the frequency of 51 Hz; 2.5 dB for 60 Hz; -1.3 dB for the frequency of 80 Hz; and 1.4 dB for 90 Hz [\[Table 4\]](#).

Relating the real sound recorded at the field, the difference between the average of the hearing threshold of the two groups corresponded to 27.2 dB. These data reveal that the “exposed” group is less sensitive to low frequencies and corroborates with the results illustrated in Figures 6 and 7, which clearly show the low sensitivity of the “exposed” group below 39 Hz, when compared to the “unexposed” group.

The audiometric tests contributed to assessing the discomfort due to real sound recorded and to demonstrating that the low-frequency pure sounds were audible [\[Table 8\]](#).

Table 8.

Minimum hearing threshold for pure sounds, by frequency band, for the “exposed” and “unexposed” groups

Frequency (Hz)		18	21	24	30	39	51	60	80	90
Hearing threshold (min)	Exposed	75.0	75.0	75.0	75.0	25.0	25.0	20.0	15.0	15.0
	Unexposed	45.0	40.0	40.0	35.0	20.0	25.0	20.0	20.0	15.0

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Finally, the performed tests revealed that the noise collected in the field (the real sound recorded) was audible at sound levels above 40 dB for the “exposed” group and 20 dB for the “unexposed” group.

Regarding the perception of discomfort due to noise of the two study groups [Figure 8]:

- (1) The perception of hearing tended to be higher for the “unexposed” group when compared to the “exposed” group;
- (2) The perception of day-to-day noise discomfort was similar for the two study groups, that is, most volunteers responded not feeling discomfort;
- (3) Only volunteers in the “exposed” group responded that noise has affected their lives. Although four of the eight volunteers from the same group “disagreed” with this statement;
- (4) Regarding the statement “I awake easily with the minimum noise,” the group’s perception of the “exposed” responses were not unanimous (three “disagreed,” one “undecided,” and four “agreed” or “strongly agreed”). In the “unexposed” group, most volunteers ($n = 4$) “agreed” or “strongly agreed;”
- (5) In the statement “I can easily get used to most of the noise,” most volunteers from the “unexposed” group ($n = 4$) “agreed” or “strongly agreed.” In the case of the “exposed” group, only three out of the eight volunteers “agreed” with this statement;
- (6) About the statement “I feel annoyed with the noise,” in both groups, most volunteers “agreed” or “strongly agreed” with this statement;
- (7) Regarding the statement, “I feel discomfort with the noise coming from outside my home,” for the “exposed” group, four volunteers “agreed” or “strongly agreed,” while in the case of the “unexposed” most volunteers ($n = 5$) “disagreed” or “strongly disagreed;”
- (8) For the statement, “I have difficulty concentrating in noisy environments,” as far as the “unexposed” group is concerned, most volunteers ($n = 4$) “disagreed” or “strongly disagreed.” In the “unexposed” group, most volunteers ($n = 6$) “agreed” or “strongly agreed;”
- (9) When confronted with the statement “I have difficulty in relaxing in noisy environments,” most volunteers ($n = 6$) from the “exposed” group “agreed” or “strongly agreed.” In the case of the “unexposed” group, the perception was divided into three who “agreed” and three who “disagreed” or “strongly disagreed;”
- (10) Finally, regarding the statement “I am aware of the impact of noise on my health,” in both groups, most “exposed” ($n = 6$) and “unexposed” ($n = 4$) volunteers “agreed” or “strongly agreed” with this statement.

Regarding the evaluation of the real sound reproduced in the audiometric booth, the groups were evaluated.

Concerning the evaluation of discomfort due to noise reproduced in the audiometric booth, the “exposed” group showed that they felt more uncomfortable with this type of noise than the “unexposed” group [Figure 9].

From the performance of the cognitive tests, in the “exposed” group [Table 6], only one participant reached 22 points, which may reveal a cognitive deficit. One of the participants reached 25 points, which represents a nonsuggestive change in deficit. For the remaining participants, three reached 26 points and the other three participants 27 points, which corresponds to a preserved cognitive function [Table 5]. Participant 5 (male, 68 years old and with 4 years of schooling), who had a cognitive deficit had been a textile carder for 44 years and retired 14 years ago. Although this participant revealed that he “strongly agreed” with the statement “I usually hear well” and that the noise had little impact on his quality of life, the participant’s hearing threshold for pure sounds was above average for low frequencies. For the real sound recorded, the hearing threshold of this participant was 60 dB (8.7 dB above the average of this group).

For the “unexposed” group [Table 7], participant number 2 (male, 44 years old and 2 years of schooling) reached 17 points, which reveals a cognitive deficit. This participant worked in civil construction for 5 years and has been unemployed for 10 years. The hearing threshold was 30 dB (5.8 dB above the mean of this group).

CONCLUSION

Due to the fact that it is a difficult study and has never been conducted in Portugal, one of the most important limitations in this type of study was the difficulty in isolating the main source under study and in the analysis of the results. The sound levels measured and the real sound recorded correspond to external ambient noise resulting from various contributions in the place. When measuring and recording the noise, other sources of low-frequency noise were captured in addition to the main source (e.g., heavy vehicle noise).

The recorded sound was audible by volunteers during audiometric tests; the hearing threshold average for recorded sound was 51.3 dB and ranged from 40 to 65 dB. For the “unexposed” group, the hearing threshold average was 24.1 dB and ranged from 20 to 30 dB. These data reveal that the “exposed” group is less sensitive to low frequencies and corroborates with the results found, which clearly show the low sensitivity that the “exposed” group presents, below 39 Hz, when compared to the “unexposed” group. According to the findings, the “exposed” group feels more uncomfortable with this type of noise than the “unexposed” group. It is important to note that age could be an important factor that can contribute to the loss of sensitivity to low frequencies observed. In the case of the “exposed” group, the average age of the volunteers was 53.8 years old, while to the “unexposed” group it was 48.3 years old [Table 6].

Regarding the various existing methodologies for the assessment of environmental noise, namely in areas with low-frequency noise sources, we propose to reduce the lower limit of frequency range, which is 50 Hz, considering the contributions of sources that emit noise below 50 Hz such as power poles and power lines. In addition, it is worth noting the use of the A filter that considerably penalizes the sound levels measured and disguises the objective parameters of evaluating discomfort due to low frequency noise. Thus, measurement and assessment of discomfort due to low-frequency noise should be made with an appropriate filter or without any filter applied, that is, in linear mode.

The methodology developed and presented here was appropriate for the intended purpose, as it enabled us to evaluate the perception of low frequency noise, as well as alert us about the necessity of extending the minimum interval of frequency in the evaluation of the impact of this type of noise in the population. It is a simple methodology, involving few steps, inexpensive and exclusively oriented towards low frequencies.

The distance between the receiver and source may interfere with the degree of discomfort experienced by individuals. For the presented results, the real sound was measured at 5 m of distance, between the receiver and source. It was observed that at this distance, noise is uncomfortable and presents levels of sound pressure above those considered safe for human health.[1,8,27] According to some authors,[1,6,26] low frequency noise could propagate over large distances and is not absorbed by most materials. As well as this factor, it is important to remember that this type of noise often has tonal characteristics, which is why it is more annoying. It is expected that in future research, this type of evaluation can be explored by varying the distance between the receiver and the source. This may provide important information on the definition of the limits for installation of power poles and power lines in residential areas, based not only on the objective component (measurement of sound levels and setting the minimum limit of evaluation below the usual 50 Hz), but considering also the subjective component, that is, the perception of discomfort reported by the exposed population. The authors believe that the relationship between low frequency noise levels and weather conditions exist and should be studied to complement this type of analysis.

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Conflicts of interest

There are no conflicts of interest.

REFERENCES

1. Alves JA, Silva LT, Remoaldo PC. The influence of low-frequency noise pollution on the quality of life and place in sustainable cities: A case study from Northern Portugal. *Sustainability*. 2015;7:13920–46. doi: 10.3390/su71013920. [[Google Scholar](#)]
2. Pawlaczyk-Luszczynska M, Szymczak W, Dudarewicz A, Sliwińska-Kowalska M. Proposed criteria for assessing low frequency noise annoyance in occupational settings. *Int J Occup Med Environ Health*. 2006;19:185–97. doi: 10.2478/v10001-006-0022-9. [[DOI](#)] [[PubMed](#)] [[Google Scholar](#)]
3. Pawlaczyk-Luszczynska M, Dudarewicz A, Szymczak W, Sliwińska-Kowalska M. Evaluation of annoyance from low frequency noise under laboratory conditions. *Noise Health*. 2010;12:166–81. doi: 10.4103/1463-1741.64974. [[DOI](#)] [[PubMed](#)] [[Google Scholar](#)]
4. Eysel-Gosepath K, Daut T, Pinger A, Lehmacher W, Erren T. Effects of noise in primary schools on health facets in German teachers. *Noise Health*. 2012;58:129–34. doi: 10.4103/1463-1741.97258. [[DOI](#)] [[PubMed](#)] [[Google Scholar](#)]
5. Vianna KM, Cardoso MR, Rodrigues RM. Noise pollution and annoyance: An urban soundscapes study. *Noise Health*. 2015;6:125–33. doi: 10.4103/1463-1741.155833. [[DOI](#)] [[PMC free article](#)] [[PubMed](#)] [[Google Scholar](#)]
6. Berglund B, Hassmén P, Job RF. Sources and effects of low-frequency noise. *J Acoust Soc Am*. 1996;5:2985–3002. doi: 10.1121/1.414863. [[DOI](#)] [[PubMed](#)] [[Google Scholar](#)]
7. Dent R. What Causes the Noise Emitted From High-Voltage Power Lines – Is It Static Discharge, Vibration From the 60-Cycle Field or Something Else Entirely? *Scientific American*. [[Last accessed on 2017 Oct 27]]. Available from: <https://www.scientificamerican.com/article/what-causes-the-noise-emi/#> .
8. Moorhouse A, Waddington D, Adams M. Procedure for the Assessment of Low-Frequency Noise Complaints. 2011. [[Last accessed on 2017 Oct 15]]. Available from: <https://core.ac.uk/download/pdf/1655460.pdf> . [[DOI](#)] [[PubMed](#)]
9. Babisch W. Traffic noise and cardiovascular disease: Epidemiological review and synthesis. *Noise Health*. 2000;8:9–32. [[PubMed](#)] [[Google Scholar](#)]
10. Passchier-Vermeer W, Passchier WF. Noise exposure and public health. *Environ Health Perspect*. 2000;1:123–31. doi: 10.1289/ehp.00108s1123. [[DOI](#)] [[PMC free article](#)] [[PubMed](#)] [[Google Scholar](#)]
11. Lercher P, Botteldooren D, Widmann U, Uhmer U, Kammeringer E. Cardiovascular effects of environmental noise: Research in Austria. *Noise Health*. 2011;5:234–50. doi: 10.4103/1463-1741.80160. [[DOI](#)] [[PubMed](#)] [[Google Scholar](#)]
12. Stansfeld S, Crombie R. Cardiovascular effects of environmental noise: Research in the United Kingdom. *Noise Health*. 2011;52:229–33. doi: 10.4103/1463-1741.80159. [[DOI](#)] [[PubMed](#)] [[Google Scholar](#)]
13. Van Kempen E. Cardiovascular effects of environmental noise: Research in The Netherlands. *Noise Health*. 2011;52:221–8. doi: 10.4103/1463-1741.80158. [[DOI](#)] [[PubMed](#)] [[Google Scholar](#)]
14. Karpova NI, Alekseev SV, Erokhin VN, Kadyskina EN, Reutov OV. Early response of the organism to low-frequency acoustical oscillations. *Noise Vib Bull*. 1970;65:100–3. [[Google Scholar](#)]

15. Brown JE, Thompson RN, Folk ED. Certain non-auditory physiological responses to noise. *Am Ind Hyg Assoc J*. 1975;36:285–91. doi: 10.1080/0002889758507249. [[DOI](#)] [[PubMed](#)] [[Google Scholar](#)]
16. Job R. The role of psychological factors in community reaction to noise. In: Vallet M, editor. *Noise as a Public Health Problem*, vol. 3. Arcueil Cedex. France: INRETS; 1993. pp. 47–79. [[Google Scholar](#)]
17. Pawlaczyk-Luszczyńska M, Dudarewicz A, Szymczak W, Waszkowska M, Sliwińska-Kowalska M. The impact of low frequency noise on human mental performance. *Int J Occup Med Environ Health*. 2005;2:185–98. [[PubMed](#)] [[Google Scholar](#)]
18. Ising H, Kruppa B. Health effects caused by noise: Evidence in the literature from the past 25 years. *Noise Health*. 2004;22:5–13. [[PubMed](#)] [[Google Scholar](#)]
19. Castelo-Branco N, Alves-Pereira M. Vibroacoustic disease. *Noise Health*. 2004;23:3–20. [[PubMed](#)] [[Google Scholar](#)]
20. Eysel-Gosepath K, Daut T, Pinger A, Lehmacher W, Erren T. Sound levels and their effects on children in a Germany primary school. *Eur Arch Otorhinolaryngol*. 2012;12:2475–83. doi: 10.1007/s00405-011-1899-x. [[DOI](#)] [[PubMed](#)] [[Google Scholar](#)]
21. Wayne KP. On the effects of environmental low frequency noise. Dissertation thesis. Gothenburg, Sweden: Gothenburg University; 1995. [[Google Scholar](#)]
22. Alves JA, Silva LT, Remoaldo PC, Arezes P, Neto Paiva FM. Proposta metodológica para avaliação audiométrica e da incomodidade ao ruído de baixa frequência. 9^o Iberian Congress and the 47th Spanish Congress on Acoustics TECNIACUSTICA®. 2016:175–6. [[Google Scholar](#)]
23. Kjellberg A, Goldstein M. Loudness assessment of band noise of varying bandwidth and spectral shape. An evaluation of various frequency weighting networks. *J Low Freq Noise Vib*. 1985;4:12–26. [[Google Scholar](#)]
24. Leventhall G. Low frequency noise and annoyance. *Noise Health*. 2004;6:59–72. [[PubMed](#)] [[Google Scholar](#)]
25. DIN: 45680. Measurement and Assessment of Low-frequency noise immissions in the neighbourhood [in German] Berlin: Deutsches Institut für Normung; 1997. [[Google Scholar](#)]
26. Silva LT. Avaliação da qualidade ambiental urbana. Portugal: Universidade do Minho (Tese de Doutoramento em Engenharia Civil); 2007. [[Google Scholar](#)]
27. Agência Portuguesa do Ambiente. Directrizes para elaboração de mapas de ruído. Portugal: APA; 2011. [[Google Scholar](#)]
28. IS 08253–1. Audiometric Test Methods, Part 1: Pure-Tone Air and Bone Conduction Threshold Audiometry. Geneva, Switzerland: International Organization for Standardization; 2010. [[Google Scholar](#)]
29. Folstein M, Folstein S, McHugh P. Mini-mental state: A practical method for grading the cognitive state of patients for the clinician. *J Psychiatr Res*. 1975;3:189–98. doi: 10.1016/0022-3956(75)90026-6. [[DOI](#)] [[PubMed](#)] [[Google Scholar](#)]
30. HIFIMAN. Headphone HE400S: Characteristics. [Last accessed on 2018 Mar 22]. Available from: <http://hifiman.com/products/detail/238>
31. DOC1081. Dbtrait Software User Manual. France: ACOEM Smart monitoring, diagnosis & solutions; 2013. [[Google Scholar](#)]

Valuation Guidelines for Properties with Electric Transmission Lines

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Before a discussion can be entered about the perception of electric transmission lines and their effect on property value, it is important to understand what a transmission line is and how it differs from a distribution line.

An electric *transmission* line is an electric line that transports electrical power from one substation to another. These lines are typically 100kV (kilovolts) or larger exceeding one mile in length¹, have large wood or steel support towers over 45ft in height, and often have more than one set of wires (3 wires per circuit plus the static wire). Electric transmission lines do not directly serve electric utility customers: their power is distributed from distribution point to distribution point. Transmission line wires are not insulated and are "bare". Typically, they constructed to have at least 20ft of clearance between the ground elevation and wire at low sag.

An electric *distribution* line is a power line that transports electricity from the substation to the electric utility customers. These lines are of less voltage, typically under 65kV, carried on wood poles of 45ft in height or less and hold one pair of wires. The voltages of these lines are downgraded before the electricity is brought to the customer's residence or commercial building. The focus of this report is on "transmission" lines, not "distribution" lines

Perception = Value

The valuation of properties that have an electric transmission line requires an understanding of the basic principles of Market Value. Market Value is defined, in layman's terms, as the value a property would sell for at a given date considering an open market. (A complete definition of this term is included in the body of the appraisal report.) An open market assumes that the property is available for purchase by the public, being properly marketed for maximum exposure, and that the buyer is well informed, fully knowledgeable and acting in their best interest. Included in this definition is that the buyer has full knowledge of the pros and cons of the property, and then acts with that knowledge in a way that will benefit them. In other words, the value of the property is based on the perception of the buyer. Understanding that perception drives value is the foundation in analyzing the effect that electric transmission lines have on property value.

The key point of the Market Value definition, which gives guidance to answer the "impact" question, is the "willing buyer" part of the equation. In appraising a property the appraiser attempts to reflect the potential buyer of the subject property and estimate their action as to the subject property with all its advantages and disadvantages (knowledgeable buyer). To accurately reflect this buyer, the appraiser must determine the typical profile of such a buyer of the property in question. An example of this

¹ Wis. Stat. 196.491(1)(f)

would be a one bedroom condominium along a lake may indicate a typical buyer to be a retired couple who is looking for a recreational retreat for themselves and their guests. Another example would be a parcel with the best use being a dairy farm; the typical buyer would be a person either currently engaged in dairy farming looking to expand or relocate, or one who desires to enter into this field -- in either case a "dairy farmer." Such an analysis should be obvious, yet often overlooked when appraising properties.

For rural properties that are utilized for agricultural purposes, the most likely buyer would be one who: (1) prefers the rural lifestyle over the urban lifestyle; (2) typically generates their income from working in the agricultural field; (3) would be sensitive to environmental issues that affect the uses of the land and the view shed of the land; and (4) would be sensitive to health and safety issues relating to the land and its use.

It is most likely that such a person, when confronted with an electric transmission line traversing the property, would view such an improvement as aesthetically "ugly," potentially hazardous to their health, disruptive to rural lifestyle and potentially harmful to the use of the land for agricultural purposes.

Research Format

Our research into the impact of electric transmission lines followed several stages. The first was a "literature" study. This study involved investigating, collecting, indexing and reading many of the published articles, news stories and published transcripts relating to the topics of EMFs and stray voltage. Stray voltage was included in this research due to the concern dairy farmers have relating to its presence from high voltage power lines. This research resulted in over 2,500 pages of information collected and analyzed. The purpose of this study was to discover "what is the public's perception of high voltage transmission lines." Overall, the majority of the articles indicated a "fear" of these power lines, citing health concerns as the primary factor. Other concerns included stray voltage issues (mainly with rural publications) and aesthetics. It was clear that most of the information the public receives about these matters is negative. The literature study will follow these "guidelines."

The second part of our study involved researching studies completed on the effects on property value due to the presence of electric transmission lines. This included collecting many of the published research studies on this topic found in the public domain. Additionally, the study reviewed trade journals not available to the public, but available only to real estate professionals. Again, to be fair, some of the studies indicated that there was no measurable effect. However, there were a number of studies (mostly recent) that indicated there was a measurable effect and that effect ranged from a loss of 10% to over 30% of the overall property value. These studies included both improved and vacant land.

Empirical Studies

Below is a sampling of some studies we have reviewed regarding the impact that electric transmission lines have on land value and were utilized to formulate our opinion of value when a property is impacted by a high voltage transmission line.

- *Study of the Impact of a 345kV Electric Transmission Line in Clark County, Town of Hendren.*

(Appraisal Group One, Kurt C. Kielisch, 2006, revised 2009) This study was limited to Hendren Township, Clark County, and covered a five year time period from January 1st, 2002 to June 1st, 2006. This study included 22 land sales of agricultural and recreation land, of which 4 were encumbered with a 345kV electric transmission line having wood H-pole design, 60ft height and 150ft wide easement. The other 18 land sales were considered comparable to the power line encumbered sales. The conclusion of this study was that: (a) the land sales with an electric transmission line sold for 23% less than comparable land sales without a transmission line; and, (b) the more severe the location of the power line the greater was the loss of value.

- *An Impact Study of a 345kV Electric Transmission Line on Rural Property Value in Marathon County - Wisconsin.* (Appraisal Group One, Kurt C. Kielisch, 2006) This study focused on the impact a 345kV line, known as the Arrowhead-Weston line, had on property value. This power line was a 345kV electric transmission line, having steel single poles ranging in height from 110ft to 150ft, single and double circuit lines, having a 120ft wide easement. The study compared sales within a 2 year time period (January 1st, 2004 to December 31st, 2005) in Marathon County, Wisconsin, focusing the area to the Townships of Cassel and Mosinee. This study used 14 land sales, of which 5 were encumbered with the power line and 9 were not. A simple regression technique and matched pair analysis was used to extract the value impact. The study concluded with a finding that when the power line traversed the property along the edge, such as a back fence line, the loss was as low as -15%, and when it bisected a large parcel the loss was as high as -34%. The properties were all raw land sales with either agricultural or residential land use.
- *Transmission Lines and Property Values State of the Science* (Electric Power Research Institute [EPRI], 2003). This study completed by EPRI for the benefit of its electric utility clients reviewed the issue of property values being impacted by electric transmission lines by summarizing research they had on the subject. Essentially they concluded that the results are mixed, some cases showing a loss in value ranging from 7-15% with appraisers who had experience with valuing such properties, to having no effect. Interestingly, it appeared in their survey that appraisers who did not have experience valuing such properties tended to overrate the negative effects.
- *American Transmission Company, Zone 4, Northeast Wisconsin - High Voltage Transmission Line Sales Study* (Rolling & Company, 2005). This study researched the impact that high voltage electrical transmission lines have on property value in the northeast Wisconsin area. They collected information on 682 land sales of which 78 involved lots near a transmission line corridor, but not directly encumbered by the transmission line. Their conclusions were: (a) easement lots sold at about 12% less than lots located over 200ft from the transmission lines; and (b) no clear impact on "proximity" lots those that lie within 200ft from the easement area but are not directly subject to the easement.

- *Properties Near Power Lines and Valuation Issues: Condemnation or Inverse Condemnation* (David Bolton, MAI. Southwestern Legal Foundation. 1993). This study cites a number of studies that prove a loss of property value due to proximity to an electric transmission line and then cites his own study. His own study found that in the Houston area assessed values of properties that adjoined a power line easement had a 12.8% to 30.7% lower assessment than the average homes not on the line, but in the same area. He also found that: (1) many buyers refused to even look at such properties; (2) such properties took at least twice as long to sell; (3) some brokers said such properties can take three times longer and finally sell at a 25% loss of value; and (4) overall homes adjoining transmission line easements took six times longer to sell and experienced a 10% to 30% loss in value.
- *Power Line Perceptions: Their Impact on Value and Market Time* (Cheryl Mitteness and Dr Steve Mooney. ARES Annual Meeting paper. 1998) The authors interviewed homeowners on or near electric transmission lines and found: (1) that in relation to the average impact of overall property value, 33% said 2-3% loss and 50% said a 5% loss or greater; (2) nearly 66% said the power line negatively affected their property value; (3) 83% of real estate appraisers surveyed said the presence of the power lines negatively affected the property values, most saying the loss was 5% or greater.
- *Analysis of Severance Damages* (James Sanders, SRA, 2007) This study completed an analysis of the impact of a transmission line through the middle of the Continental Ranch subdivision outside of the Tucson, Arizona area. This subdivision had a wood H-pole high voltage electric transmission line running through a portion of the subdivision. The author compared the residential lots abutting the easement to ones that were not. All lots abutting the easement were much bigger than the non-easement abutting lots. The author used improved properties for his study and by the use of regression analysis isolated many variables of value for an improved property to remove them from the analysis. In conclusion, through extensive use of the regression technique, the author finds an overall loss to the improved properties abutting the power line easement at -12%. This loss is attributed to both the land and improvements. However, the author notes that the lots are typically twice the size of the non-easement lots. When the size of lots was factored the overall loss to the land only was factored at -40%. It should be noted that the residences were at a distance from the power line.
- *The Peggy Tierney property: A Comparative Study of the Impact of a 69kV Transmission Line v. 345kV/69kV Transmission Line* (Kurt C. Kielisch). This was a brief study on the impact difference, if any, between an existing 69kV transmission line and a new proposed 345kV and 69kV transmission line on the same property. The property was a 3.70 acre residential lake front improved property that had an existing 69kV transmission line crossing the west half of the parcel along the road and required the property owner to cross under the power line to enter the parcel. The 69kV line had an easement width of approximately 100ft, wood H-poles at 50-60ft in height. The new 345kV line was to be placed within the existing easement, more or less, would have 140ft monopoles and carries both a 345kV and 69kV line. The seller attempted to sell the property at its full list price after an experienced lake front home Realtor established the list price from a comparative sales analysis. The home eventually sold for 27% less than the list price and took longer to sell in a relatively strong lake front home market. The buyer cited the pending 345kV line as the principle reason for their low offer.
- A comparative sales analysis to isolate the percentage of loss a residential and/or agricultural

land use property suffers due to the presence of a high voltage electric transmission line (HVTL). This study was found in an appraisal completed by Aari K. Roberts for American Transmission Corporation (ATC) on the Herbert Bolz property located in the Town of Rubicon, Dodge County, Wisconsin. Mr. Roberts compared the sale of a rural agricultural 24 acre land parcel that had an HVTL crossing the property, to three comparable agricultural land sales of comparability that did not have a HVTL. His sales comparison study concluded that the property with a HVTL suffered a 29% loss of value due to the presence of the HVTL. This study was completed in September 2007.

- A sales analysis of the property located at: N8602 CTH D, Town of Deer Creek, Outagamie County, Wisconsin. This is a single family home located on 3.19 acres in the rural area of Outagamie County. The home was a ranch style residence with 1,500sf GLA, attached 2-car garage, 8/3/2 room count, full basement and was in average condition overall. The property also had a 104ft x 52ft pole barn and two other outbuildings. There were two appraisals completed on this property, one by the condemnor (ATC) and one by the property owner. The average Before taking value of the two appraisals was \$221,000. The property was then improved with a 345kV & 138kV electric transmission line having 126ft pole height and was placed along the roadside reaching 68ft into the property. The edge of the easement was in less than 20ft to the residence, however the placement of the pole was as close to the roadway right-of-way as possible. The condemnor American Transmission Company (ATC) purchased the property and installed the transmission line. Then they upgraded the property with new paint, doors, sinks, dishwasher and flooring, plus cleaned the premises and outbuildings. ATC put the property on the market asking \$179,900 a number established by the appraiser for ATC as the After value. It was sold for \$128,500 10 months after ATC purchased it.

The Before taking average value was \$221,000. The property was then improved and upgraded at an expense estimated to be \$8,000-\$10,000, then resold 10 months later with the transmission lines in place for \$92,500 less or 42% less. The only differences between the Before taking market value and After taking sale price were the transmission line and time. A review of the Outagamie County market between November 2008 and September 2009 shows only a small downward trend in rural residential property value, therefore the biggest part of the loss is attributed to the presence and near proximity of the transmission line that being 38%-40%.

- *The Gene Laajala property: A Comparative Study of the Impact of a 161kV Transmission Line v. 345kV/161kV Transmission Line (Kurt C. Kielisch).* This was a brief sales study on the impact difference, between an existing 161kV transmission line and a new 345kV/161kV transmission line on the same property. The property was a 20 acre rural agricultural and residential property that had an existing 161kV transmission line bisecting the parcel along the east side. The 161kV line had an easement width of approximately 120ft, wood H-poles at 50ft± in height. This line was replaced with an upgraded easement comprised of 345kV/161kV line which was to be placed within the existing easement, more or less, and had (2) 110ft and (3) 120ft steel H-poles. The property was appraised in January 2007 with a Before condition value of \$204,500 using the Cost approach and \$185,500 using the Comparable Sale approach, by Ted Morgan, MAI. (The whole property appraised was 40 acres and the 20 acre parcel was portion out of this whole). The ATC appraiser did not appraise the home in the Before condition, but did conclude the Before taking land value was \$44,000 for 20 acres (using his \$2,200/acre conclusion for 40 acres) and the assessed value of the improvements were \$107,600, indicating a \$151,600 Before

value. The property sold and closed in October 2007 for \$120,000. The seller attributes the loss to the new power line, it being larger and more lines. The loss indicated was \$65,500 (using Morgan's Comparable Sales value) or \$31,600 (using ATC's land plus assessed improvement value), indicating a loss range of 35% to 21%.

- *An Impact Study of the Effect of High Voltage Power Lines on Rural Property Value in Southwestern Indiana (Kurt C. Kielisch, Appraisal Group One, 2010).* This study was based in southwest Indiana in Gibson County. It was focused on large agricultural land and the impact of a high voltage transmission lines (HVTL) varying in size from monopole to large steel lattice towers. The study included 32 land sales of which 10 were HVTL sales. The time period was January 1st, 2006 to December 31st, 2009. Adjustments were made for time, location and other utility easements (if any) and the results were graphed to compare the non-HVTL land sales to the HVTL land sales. The study concluded that the power lines negatively impacted the property with an impact range from -5% to -36% with the average impact being -20%.

Other Value Issues

Another issue relating to the presence of the transmission line is potential for the creation of an "utility" corridor. Such a corridor is a where several utility transmission lines are placed, such as gas transmission pipelines and communication lines. Indeed, the State of Wisconsin made it a legislative rule that future placement of such utilities are to be given preference to "existing utility corridors."² An electric transmission line meets the definition in this statute as an existing corridor. This "corridor" concept continues to grow in the perception of the public as such rules become more commonly known. The reality of such an event happening is the placement of the Arrowhead-Weston Power line, which was often placed within an existing utility corridor such as an oil transmission pipeline, smaller electrical transmission lines or abandoned electric transmission line easements. The very power line that is the focus of this analysis is further proof of the corridor effect for it has been expanded, enlarged and added circuits within the existing easement.

Other factors to consider regarding the valuation of HVTL impacted rural properties are agricultural equipment concerns operating under and near the line, health issues of workers in close proximity of the lines, health concerns of farm animals in close proximity of the lines, stray voltage, the concerns of public in relation to electro-magnetic fields, safety issues regarding bare wires of the transmission line and other concerns addressed in the literature study to follow.

In conclusion, it can be stated with a high degree of certainty that there is a significant negative effect ranging from -10% to -30% of property value due to the presence of the high voltage electric transmission line. The actual loss depends on factors of land use, location of the power line and its size.

² Wis. Stats 1.12(6)(a).

Literature Study

HVTL Impacts on Rural and Agricultural Properties

Throughout the nation's rural communities, literature research suggests that the presence of an HVTL easement can have a noticeable impact on both the use and appeal of rural properties and farms. Common concerns include stray voltage, health risks to livestock and cattle, diminished livelihoods and heritage, limited land use, and lessened aesthetic appeal. As the following literature survey will show, many different issues play a role in shaping one's perception of the impact of HVTLs on rural property values.

Stray Voltage

To understand the potential impact of HVTLs on rural land, it's important to discuss a key component in many farmers' apprehension about HVTLs: stray voltage.

Stray voltage is the rural equivalent of the high-profile residential Electromagnetic Field (EMF) factor, but instead of fearing leukemia or brain cancer, farmers fear their animals will become unproductive, ill, and even die.

Whenever energy is transferred, some is lost along the way. If metal buildings are near leaking energy, they can act as a conduit for voltage to find its way to feeding systems, milking systems and stalls.

In their 1995 presentation, "Stray Voltage: The Wisconsin Experience," a team of researchers led by Mark Cook and Daniel Dascho stated that farmers most worry that stray voltage will increase somatic cell count in their animals, make cows nervous, reduce milk production, and increase clinical mastitis.³

"Few issues are more upsetting to dairymen than fighting case after case of clinical mastitis with more and more cows in the sick pen," writes Dr. Winston Ingalls. "It represents extra time to properly handle such cows, lost production, vet calls, treatment products, concern about contaminated milk and an occasional dead or culled cow."⁴

In Cook & Dascho's presentation, they discuss their findings from a non-random sampling study of farms with stray voltage complaints stemming from a nearby substation. Their research team found no significant relationship between cow contact current and distance from the substation or contact currents. However, they also noted that cow contact current depends on many physical factors from on-farm and off-farm electrical power systems. They say, "There are many confounding factors that may outweigh the impacts of stray voltage which makes it difficult to draw conclusions from field studies about its effects on production and animal health."⁵

3 **Stray Voltage: The Wisconsin Experience.** Written for presentation at the 1995 International Meeting by Mark A Cook, Daniel M Dascho, Richard Reines and Dr. Douglas J Reinemann.

4 **Clinical Mastitis.** Winston Ingalls, Ph.D. GoatConnection.com. August 2, 2003.
http://goatconnection.com/articles/publish/article_173.shtml

5 **Stray Voltage: The Wisconsin Experience.** Written for presentation at the 1995 International Meeting by Mark A Cook, Daniel M Dascho, Richard Reines and Dr. Douglas J Reinemann.

In a 2003 study prepared for the NRAES Stray Voltage and Dairy Farms Conference, a research team conducted by the University of Wisconsin-Madison and led by Dr. Douglas J Reinemann studied the effects of stray voltage on cows at four dairy farms over a two-week time period. He and his team found that after the first few days of exposure, cows quickly acclimated to the presence of stray voltage. They also found that stray voltage of 1mA had little effect on the immune system of a cow.⁶

Concerning EMF levels, they noted that "even though man-made signals were larger than the naturally occurring currents, levels are significantly lower than what is considered sufficient earth current strength to develop step potential anywhere near the Public Service Commission 'level of concern.'"⁷

Stray voltage is usually undetectable by humans, and some researchers believe it occurs when electricity escapes a power line or wiring system and emits a secondary current. The problem intensifies with older barns that add automated electrical equipment, "raising ambient levels of current. Soon the cumulative effect of these secondary currents becomes harmful to cows." Though stray voltage can be measured, experts don't know how and why it happens or what conclusive effect (if any) it has on animals.⁸

Despite little concrete evidence, courts have compensated farmers for their losses due to stray voltage when all other factors are eliminated. In 1999 a jury awarded Peterson Bros. Dairy \$700,000 after deciding that stray voltage from an automated feeding system from Maddalena's Dairy Equipment of Petaluma, California slashed the herd's milk output and increased the cow's death rate.⁹

The company's defense attorney called stray voltage "junk science," the Petersons' claim of stray voltage in the milk barn a "harebrained theory" unsupported by electrical engineers, and blamed the herd's health problems on the Petersons' own mismanagement.¹⁰

In a similar case in Wisconsin in 2004, a dairy operation owned by George and Kathy Muth successfully sued Wisconsin Electric Power Co. (now We Energies) for negligence in the maintenance and operation of a distribution system on their farm. They claimed that the system led to stray voltage that injured and killed several of their dairy cows and damaged their milk production. The utility said that the levels of stray voltage were "extremely low" and were levels you could find anywhere.¹¹

6 Dairy Cow Response to the Electrical Environment: A Summary of Research conducted at the University of Wisconsin-Madison. Paper presented at the NRAES Stray Voltage and Dairy Farms Conference. Dr. Douglas J. Reinemann. April 2003.

7 Results of the University of Wisconsin Stray Voltage Earth-Current Measurement Experiment. A revised version of a report submitted to the State of Wisconsin Legislature on June 25, 2003. Written by David L. Alumbaugh and Dr. Louise Pellerin.

8 Jury gives \$700,000 to dairy farmers for losses blamed on "stray voltage." Author Unknown. The Associated Press. April 21, 1999.

9 Ibid.

10 Ibid.

11 Power company negligent in dairy suit; Jury awards \$850,000 to couple over effect of stray voltage on cows. Lauria Lynch-German. Milwaukee Journal Sentinel. February 27, 2004.

The farmers said that shortly after moving to their new location, they faced low milk production, excessive illnesses, and deaths of cows.¹² The cows didn't walk right or act normal. They didn't want to go into the barn, inside, or into the stalls. The Muths examined everything from the animals' food to their bedding until consultants told them it could be stray voltage. In one year, they lost 15-18 cows and calves. Autopsies were inconclusive.¹³

After reviewing herd management and nutrition, they hired a consultant who detected stray voltage. Later that year the utility found no stray voltage problems. The farmers further consulted with veterinarians and tested and ruled out all the other factors except for stray voltage.¹⁴

The farmers hired an electrician to upgrade the farm's wiring, but it didn't decrease the stray voltage. After being asked, the utility made some other changes, but this also had no effect. Further consultants still found stray voltage from a conductor on the utility's distribution lines. A couple years later the utility removed a piece of underground electrical equipment and the herd immediately recovered...though the level of stray voltage remained the same.¹⁵

The utility's attorney stated that being able to measure something doesn't make it harmful. He cited several federal and state studies that say the current must be 2 milliamps or higher to adversely affect cattle and said no reading on their farm reached that level.¹⁶

The jury awarded the dairy farm \$850,000 in damages.¹⁷

Stray voltage fears aren't limited to dairy or cattle operations. Max Hempt, a horse farm owner in Pennsylvania, tried to oppose a proposed 9-mile 138kV HVTL because he feared that the line's EMFs caused by stray voltage could cause sterility and death among his horses.¹⁸

Though it's difficult to prove a significant presence of stray voltage, and even more difficult to prove a direct correlation between stray voltage and poor health, courts have awarded farmers sizable judgments to compensate them for damaging stray voltage from nearby power lines.

In 2002, one such case in Iowa made it to the state supreme court where the court upheld a \$700,000 judgment to a dairy farmer who argued that stray voltage from nearby power lines injured his herd. A substation sits less than a quarter mile from his farm. He said he often got electric shocks from the metal buildings on the farm. Also, he said his herd acted oddly, appearing frightened and refusing to enter barns. Milk production also suffered.¹⁹

12 Jury must decide in voltage complaint; Farm family says stray power harmed dairy herd. Lauria Lynch-German. Milwaukee Journal Sentinel. February 5, 2004.

13 Dairy farm owner testifies that stray voltage killed cows in his herd. Lauria Lynch-German. Milwaukee Journal Sentinel. February 10, 2004.

14 Jury must decide in voltage complaint; Farm family says stray power harmed dairy herd. Lauria Lynch-German. Milwaukee Journal Sentinel. February 5, 2004.

15 Ibid.

16 Ibid.

17 Power company negligent in dairy suit; Jury awards \$850,000 to couple over effect of stray voltage on cows. Lauria Lynch-German. Milwaukee Journal Sentinel. February 27, 2004.

18 Farmer Fears Stray Voltage From PP&L 138 kV Line Could Harm His Horses. Author Unknown. Northeast Power Report. June 24, 1994.

19 Court upholds stray voltage judgment. Mike Glover. The Associated Press. October 10, 2002.

The defendant, Interstate Power Co., said that “there’s an inherent risk to transmitting electricity” and it shouldn’t be vulnerable to such lawsuits unless they were negligent. The court ruled in favor of the dairy farmer, citing the lack of a statute exempting electric utilities from nuisance claims.²⁰

One year later the Wisconsin Supreme Court similarly found “that a utility can be held responsible for harming the health of a dairy herd with stray voltage even though state-recommended voltage tests did not find potentially damaging levels where the animals congregated.”²¹

As the preceding case studies show, courts have acknowledged stray voltage and its possible effects. However, to fully understand the apprehension surrounding power lines, one must examine the EMF debate and its fear factor.

EMFs and Fear

In 1990, the EMF debate was so prevalent that members of Congress passed a bill that would limit the public’s exposure to EMFs.²² A couple years later, in response to public concern about EMFs, Congress established the EMF-RAPID program in 1992. Its purpose was to coordinate and execute a limited research program to fill information gaps concerning the potential health effects of exposure to EMFs, to achieve credibility with the public that previous research has not earned, and to coordinate and unify federal agencies’ public messages about possible EMF effects.²³ The program originally was to receive \$65 million in funding, but total funding is expected to be \$46 million.²⁴

Several years later in 1999, the National Institute of Environmental Health Sciences studied the health effects of EMF exposure and found conflicting results. Though they concluded that the evidence is weak linking EMFs to health risks, they also found that the most common health risk was leukemia (mostly appearing in children). They also found a fairly consistent pattern of a small, increased risk of childhood leukemia with increasing exposure. The majority of the panel’s voting members voted to acknowledge EMFs as a possible human carcinogen. They concluded that ELF-EMF exposure cannot be recognized as entirely safe because of weak scientific evidence.²⁵

In 2005, UK scientists conducted a case-control study on childhood cancer in relation to distance from high voltage power lines in England and Wales. They found an association between childhood leukemia and proximity of home address at birth to HVTLS. “The apparent risk extends to a greater distance than

²⁰ Ibid.

²¹ **Utility liable for stray voltage, high court says.** Don Behm. Milwaukee Journal-Sentinel. June 26, 2003.

²² **Electric Powerlines: Health and Public Policy Implications** – Oversight Hearing before the Subcommittee on General Oversight and Investigations of the Committee on Interior and Insular Affairs House of Representatives, 101st Congress, second session on electric powerlines: health and public policy implications. March 8, 1990.

²³ **Electric and Magnetic Fields Research Program** by Mr. Mukowski from the Committee on Energy and Natural Resources. 105th Congress, first session. June 12, 1997.

²⁴ Ibid.

²⁵ **NIEHS Report on Health Effects from Exposure to Power-Line Frequency Electric and Magnetic Fields.** Released by the National Institute of Environmental Health Sciences on May 4, 1999.

would have been expected from previous studies” although they have yet to discover an “accepted biological mechanism” to explain their results.²⁶

Though an accepted biological mechanism remains elusive, an early nineties case made it possible to link loss of property value to a fear of EMFs. In the 1993 case, *Criscuola v. Power Authority of the State of New York*, the court found that, “there should be no requirement that the claimant must establish the reasonableness of a fear or perception of danger or of health risks from exposure to high voltage power lines” and “Whether the danger is a scientifically genuine or verifiable fact should be irrelevant to the central issue of its market value impact.”²⁷

Utilities say that landowners should not be able to recover damages or injunctive relief “based on myth, superstition or fear about an alleged health risk that is not supported by substantial scientific or medical evidence.”²⁸

With the EMF debate unresolved, and evidence for both sides of the argument, some communities are reluctant to approve new HVTLs...and may even legally oppose them.

In an effort to preempt public opposition, Public Service Enterprise Group offered hundreds of thousands of dollars to New Jersey towns opposing its proposed HVTL project if the towns dropped all opposition and didn’t comment on the payments. Opponents called them “bribes.” The utility called them “settlements” to help minimize impacts of the project on towns and residents.²⁹

Some towns accepted payment, but the majority did not. Either they said they didn’t have enough time to respond to the offer, or they rejected them as payoffs. One of the opposing mayors, Mayor James Sandham of Montville, said it’s not about the money; “It’s about safety and property values.”³⁰

HVTLs and Property Values

Fear can impact the public’s buying habits. Residential homeowners’ resistance to abutting HVTLs is well documented. Though homeowners may fear negative effects on their community and environment,³¹ their first point of opposition is usually safety, especially if there are many children in the neighborhood. Though the 1979 Wertheimer study linking EMFs to childhood leukemia has long been contested, supported, and contested again, the very existence of a debate about the safety of EMFs sows enough doubt in residents’ minds to justify the fear.³² And that fear can influence the values of nearby homes.^{33 34 35 36}

26 **Childhood cancer in relation to distance from high voltage power lines in England and Wales: a case-control study.** Gerald Draper, Tim Vincent, Mary E Kroll, John Swanson. *British Medical Journal* (bmj.com). June 3, 2005.

27 **‘Criscuola’ – The Sparks Are Still Flying.** Michael Rikon. *New York Law Journal*. April 24, 1996.

28 **High Court Hears Arguments Today on EMF Claims.** Todd Woody. *The Recorder*. June 6, 1996.

29 **Opponents of \$750M N.J. power line project argue towns were paid to drop opposition.** Lawrence Ragonese. The Star-Ledger. January 31, 2010.

30 *Ibid.*

31 **NY Power Line Opponents Win Court Fight.** Associated Press. *New York Post*. February 20, 2009.

32 **Lines in Sand and Sky.** B.Z. Khasru. *Fairfield County Business Journal*. September 3, 2001. Vol. 40 Issue 36, p3, 2p.

33 **Power line plan concerns metro residents.** Melissa Maynarich. *News 9 (Oklahoma)*. July 22, 2008.

When given the choice to purchase two identical homes, one with such health concerns and the other without, most buyers will choose the home without the concern,³⁷ forcing the homeowner to lower their price. Aesthetic impact can also influence a property's value. Many residents don't want to look at HVTLs,³⁸ something they consider to be an "eyesore."³⁹

One of the hardest properties to sell can be one encumbered by an HVTL. Unlike roadway proximity, its effect isn't readily noticeable or measurable. Though homes near HVTLs typically have larger lots (and that can be a benefit), the biggest disadvantage is the fear factor surrounding EMFs.⁴⁰

In the early nineties, when EMFs were just entering the public consciousness, it was difficult to find a measurable price difference between homes close to an HVTL and those that were not.⁴¹ However, two researchers (Hsiang-te Kung & Charles F Seagle) conducted a case study on the impact of power transmission lines on property values and found that such negligible results depended almost entirely on the public's ignorance of EMFs and their related issues. They also found that the amount of potential property loss increased dramatically the more homeowners were aware of the potential health impacts of EMFs.⁴²

The effect of HVTLs on property values has long been a matter of contention with many studies either proving a diminutive effect or none at all. Methodologies differ and different areas of the country register different results. Some markets (ex. high-end homes) are very sensitive to HVTLs whereas others (ex. low-end homes) hardly notice them. The size of the line and the pylons are also a factor. A 69kV power line will have less effect than will a 1,200kV power line. Distance from the easement also matters. Some studies combine homes thousands of feet from HVTLs with those directly encumbered. Research sponsors also may play a factor with many being funded by the utilities themselves.

For example, in a 2007 study funded by a utility, researchers Jennifer Pitts and Thomas Jackson conducted market interviews, literature research and empirical research and reported little (if any) impact of power lines on property values. However, they did note that there is an increasing recent opinion that proximity to power lines has a slight negative effect on property values.⁴³

34 **Power Line Worries Landowners.** Ben Fischer. The Wisconsin State Journal. June 3, 2006.

35 **Lines in Sand and Sky.** B.Z. Khasru. Fairfield County Business Journal. September 3, 2001. Vol. 40 Issue 36, p3, 2p.

36 **Commissioners voice opposition to transmission lines.** David Rupkalvis. The Graham Leader. February 9, 2010.

37 **Real Estate Agents on Property Value Declines.** 4 Realtor opinion letters submitted to residents in the Sunfish, MN area whose properties are being affected by an HVTL.

38 *Ibid.*

39 **Power line plan concerns metro residents.** Melissa Maynarich. News 9 (Oklahoma). July 22, 2008.

40 **High Voltage Transmission Lines, Electric and Magnetic Fields (EMF's) And How They Affect Real Estate Prices.** David Blockhus. January 3rd, 2008. <http://siliconvalleyrealestateinfo.com/electric-and-magnetic-fields-emfs-and-how-they-effect-real-estate-prices.html>

41 **Impact of power transmission lines on property values: A case study.** Hsiang-te Kung & Charles F Seagle. Appraisal Journal. Vol. 60, Issue 3, p.413, 6p. July 1992.

42 *Ibid.*

43 **Power lines and property values revisited.** Jennifer M. Pitts & Thomas O. Jackson. Appraisal Journal. Fall, 2007.

Two California appraisers, David Harding and Arthur Gimmy, published a rebuttal to the Pitts-Jackson study that disagreed with their methodology, took issue with their sponsor, addressed omitted information, and failure to conduct before-and-after cost comparisons.⁴⁴

Pitts and Jackson responded to the rebuttal and defended their methodology, saying they purposely limited their literature research to only include empirical, peer-reviewed articles from *The Appraisal Journal* and the American Real Estate Society journals. They acknowledged they conducted the research for "a litigation matter" but did not elaborate on their sponsor.⁴⁵

In a similar case, researchers James A Chalmers and Frank A Voorvaart published a large study spanning nearly 10 years and over 1,200 properties in which they found that an encumbering HVTL had only a small negative effect on the sale price of a residential home. In half of their samples they found consistent negative property values mostly limited to less than 10%, with most between 3%-6%.⁴⁶

They summarized their findings as showing "no evidence of systematic effects of either proximity or visibility of 345-kV (kilovolt) transmission lines on residential real estate values."⁴⁷

They did, however, say that "An opinion supporting HVTLS effects would have to be based on market data particular to the situation in question and could not be presumed or based on casual, anecdotal observation. It is fair to presume that the direction of the effect would in most circumstances be negative, but the existence of a measureable effect and the magnitude of such an effect can only be determined by empirical analysis of actual market transactions."⁴⁸

Appraiser Kerry M. Jorgensen disagreed with the authors' views that paired data analysis and retroactive appraisal were "too unrefined and too subjective to be of much value," and that only through objective statistics could the effect of HVTLS on property value be truly understood. He argued that relying too much on statistics can be dangerous as there could be problems with how the data is compiled and interpreted. For example, he points out that out of their set of 1,286 qualifying sales, only 78 (6%) are directly encumbered by a power line easement, and only 33 (2.6%) more are within 246 feet of a power line easement.⁴⁹

44 **Comments on "Property Lines and Property Values Revisited."**(Letter to the editor) David M. Harding & Arthur E. Gimmy & Thomas O. Jackson & Jennifer M. Pitts. *Appraisal Journal*. Winter, 2008.
<http://www.entrepreneur.com/tradejournals/article/176131510.html>

45 Ibid.

46 **High-Voltage Transmission Lines: Proximity, Visibility, and Encumbrance Effects.** James A Chalmers and Frank A Voorvaart. *The Appraisal Journal* via the Appraisal Institute website. Volume 77, Issue 3; Summer, 2009; pages 227-246. Reposted by CostBenefit of the Environmental Valuation and Cost-Benefit News blog -
<http://www.envirovaluation.org/index.php/2009/11/09/high-voltage-transmission-lines-proximity-visibility-and-encumbrance-effects>

47 **Power Lines Don't Affect Property Values.** *The Appraisal Journal*. July 30, 2009.
http://www.appraisalinstitute.org/about/news/2009/073009_TAJ.aspx

48 **High-Voltage Transmission Lines: Proximity, Visibility, and Encumbrance Effects.** James A. Chalmers, PhD and Frank A. Voorvaart, PhD. *The Appraisal Journal*. Summer 2009. Pgs. 227-245.

49 **Letters to the Editor.** Kerry M. Jorgensen. *Appraisal Journal*. January 1, 2010.
[http://www.thefreelibrary.com/Comments+on+\"high-voltage+transmission+lines:+proximity,+visibility,...-a0220765052](http://www.thefreelibrary.com/Comments+on+\)

The Chalmers-Voorvaart study also attracted the interest of Washington Post Real Estate writer Elizabeth Razzi who wrote that the study was paid for by Northeast Utilities and completed before they proposed a high-voltage transmission grid in New England. She also wrote that both Chalmers and Voorvaart are appraisers and expert witnesses for the power industry.⁵⁰

Several studies have found that, over time, property value damages from nearby HVTLs diminish though properties near the pylons stay permanently damaged no matter the elapsed time.⁵¹ In the first case, though the property owner may grow accustomed to HVTLs and thus think less of them, new potential buyers aren't as sensitized and the diminutive impact is fresh to them.

Realtors usually oppose HVTLs. Nearly all surveyed realtors and appraisers in the Roanoke and New River valleys of Virginia said that close proximity to HVTLs would diminish property values by as much as \$25,000, but mostly for high-end homes. Lower-end homes see little impact.⁵²

Diminished property values can also impact communities. In one case, Delaware residents were worried that a proposed 1,200 megawatt HVTL would depress local property values, thus weakening the local tax base and leading to higher taxes to offset the losses. Kent Sick, author of a 1999 paper on power lines and property values, projects losses from a few percentage points to 53%.⁵³

In Atlanta, a local realty group named Bankston Realty ranked power lines as the number one item that damages resale value, followed closely by busy roads and inferior lot topography. They advise buyers to pay 15% less of the asking price if power lines are present, and they advise sellers to accept it as a logical perception of value.⁵⁴

Evidence suggests that HVTLs affect the health of residents in close proximity to lines 345kV and higher. Evidence also suggests that the power lines have little to no impact on property values because encumbered lots are often larger and more private than unencumbered lots, resulting in no diminution of purchase price. However, most studies did observe longer time on the market for encumbered properties.⁵⁵

Rural Impact

Now that the reader is aware of stray voltage, EMFs, and property values, the reader will have a deeper understanding of the potential effects of HVTLs on rural land throughout the United States.

50 **Do High-Voltage Lines Zap Property Values?** Elizabeth Razzi. Local Address. August 4, 2009. http://voices.washingtonpost.com/local-address/2009/08/do_high-voltage_lines_zap_prop.html

51 **The Effect of Public Perception on Residential Property Values in Close Proximity to Electricity Distribution Equipment.** Sally Sims, B.Sc. Paper presented to the Ph.D. Forum at the Pacific Rim Real Estate Society Conference. January 2002. This is the first part to the study.

52 **A Question of Power: Part III – Realtors: High voltage lines lower property values.** Leslie Brown. Roanoke Times. 1998. <http://www.vaproperyrights.org/articles/98lineslowervalues.html>

53 **Expert: Power lines hurt property value, market research shows sellers lose up to 53 percent.** Elizabeth Cooper. Gannett News Service. May 20th, 2006.

54 **Atlanta Homes and Resale Value... Power lines are a definite NO.** The Bankston Group. July 17, 2008. <http://atlantaintheknow.com/2008/07/17/atlanta-homes-and-resale-value-power-lines-are-a-definite-no/>

55 **High Voltage Power Lines Impact On Nearby Property Values.** Ben Beasley. Right of Way Magazine. February 1991.

In Goodhue County, Minnesota, an area locally known for protecting agriculture, CapX2020 (a utility consortium) is proposing to build a 345kV HVTL through the county that may be doubled to 690kV. Local landowner Linda Grovender voiced her concern in a 2010 letter to the editor of the Cannon Falls Beacon. She worries that the line, proposed to traverse residential and agricultural lands instead of following existing utility right-of-way, will have an adverse effect on her family's health (due to EMFs), jeopardize agricultural interests, result in lost agricultural productivity, and damage property values.⁵⁶ She wrote that if the proposed 345kV HVTL is doubled to 690kV (as it legally could be) it could have an adverse effect on her family's health, jeopardize agricultural interests, result in lost agricultural productivity, and damage property values.⁵⁷

Elsewhere in Minnesota, Dairyland Power Cooperative (one of the chief members of CapX2020) surveyed rural landowners for their opinion regarding the proposed HVTL in their area. Whether they were crop or dairy farmers, each had several reasons why the proposed line would impact their business. The unnamed respondents shared Grovender's views and said they prefer to use highway corridors and woodlands to avoid impacts to productive agricultural land; protect livestock; avoid interference with large farm equipment, GPS, and navigation systems used in farm machinery; preserve open channels for crop-dusting; protect farm buildings; protect pasture land, tree farms, and timber production.⁵⁸

The Dairyland survey also found that livestock operations are concerned that the HVTL will generate stray voltage, impacting livestock and feedlots. Cattle, horses, and other livestock will not go near transmission lines due to stray voltage. And stray voltage can impact the health of beef cattle and hogs. Farmers also fear potential impacts on dairy operations, poultry, livestock mortality, horse boarding facilities, and herd reproduction.⁵⁹

HVTLs also pose potential technological obstacles. For example, The GPS equipment used in the farm equipment may not be able to steer around transmission poles, potentially making farming around the towers extremely difficult.⁶⁰

One major concern was the routing the HVTLs through the middle of properties or fields. The surveyed farmers quoted many repercussions for bisecting a property. They include: Interrupted irrigation and tile drainage equipment and practices; decreased food production; fragmented existing cropland and dairy operations; diminished lease value: the addition of transmission lines would make it difficult to lease farm land for the top rental price; compacted soil from construction of the HVTLs and access roads: it would take 3–5 years to restore.⁶¹

Across the border in Wisconsin, the state's Department of Agriculture validated many of the Minnesota respondents' concerns when it found that HVTL construction could compact soil, making it difficult to

⁵⁶ **No CAPX2020.** Letter to the Editor by Linda Grovender. The Cannon Falls Beacon. March 23, 2010.

⁵⁷ **Ibid.**

⁵⁸ **SE Twin Cities-Rochester-La Crosse Transmission System Improvement Project Macro-Corridor Study, Appendix A: Summary of Public Comments regarding a proposed HVTL.** Dairyland Farm Cooperative. September 2007.

⁵⁹ **SE Twin Cities-Rochester-La Crosse Transmission System Improvement Project Macro-Corridor Study, Appendix A: Summary of Public Comments regarding a proposed HVTL.** Dairyland Farm Cooperative. September 2007.

⁶⁰ **Ibid.**

⁶¹ **Ibid.**

plow and plant those areas, naturally resulting in reduced crop yields. The HVTLs force farmers to change planting patterns to avoid support structures. Since farm land is only as valuable as its ability to yield good crops, rural property values suffer from the limitations and effects of HVTLs on their land.⁶²

Potential compaction, forced building changes, and lower property values equally threaten dairy operations as much as agricultural farmers. Susan and Robert Herckendorf, dairy farmers in the path of the proposed A-W HVTL, are worried that the line could put local dairies out of business.⁶³

In researching the possible negative factors of the then-proposed Arrowhead-Weston HVTL in Wisconsin in 2000, the state's Public Service Commission found that rural property values may decrease from "concern or fear of possible health effects from electric or magnetic fields; The potential noise and visual unattractiveness of the transmission line; Potential interference with farming operations or foreclosure of present or future land uses."⁶⁴ They also found that the value of agricultural property will likely decrease if the pylons inhibit farm operations.⁶⁵ However, they also found that adverse effects appear to diminish over time.⁶⁶

The impact report further states that, on farmland, HVTL installation can remove land from production, interfere with operation of equipment, create safety hazards, and deprive landowners the opportunity to consolidate farmlands or develop the land for another use. The greatest impact on farm property values is likely to occur on intensively managed agricultural lands.⁶⁷

Nearly a decade later in 2009, the Wisconsin Public Service Commission conducted another study on the environmental impacts of transmission lines and found that "in agricultural areas, the number of poles crossing a field may be the most significant measure of impact," and "agricultural values are likely to decrease if the transmission line poles are in a location that inhibits farm operations."⁶⁸ Beyond the impact of pole placement, the PSC found that "the overall aesthetic effect of a transmission line is likely to be negative to most people, especially where proposed lines would cross natural landscapes. The tall steel or wide 'H-frame' structures may seem out of proportion and not compatible with agricultural landscapes or wetlands."⁶⁹ They further explained that "Transmission lines can affect farm operations and increase costs for the farm operator. Potential impacts depend on the transmission line design and the type of farming. Transmission lines can affect field operations, irrigation, aerial spraying, wind breaks, and future land development."⁷⁰

The study further examines how rural HVTL pole placements can affect agricultural land values: They can create problems for turning field machinery and maintaining efficient fieldwork patterns; expose

62 **Line could affect farms, property values.** Author Unknown. Oshkosh Northwestern. June 26, 2000.

63 **Ibid.**

64 **Property Values (pages 212-215) from Final Environmental Impact Statement, Arrowhead-Weston Electric Transmission Line Project, Volume 1.** Public Service Commission of Wisconsin. Docket 05-CE-113. Date issued, October 2000.

65 **Ibid..**

66 **Ibid.**

67 **Property Values (pages 212-215) from Final Environmental Impact Statement, Arrowhead-Weston Electric Transmission Line Project, Volume 1.** Public Service Commission of Wisconsin. Docket 05-CE-113. Date issued, October 2000.

68 **Environmental Impacts of Transmission Lines.** Public Service Commission of Wisconsin. March 2009.

69 **Ibid.**

70 **Ibid.**

properties to weed encroachment; compact soils and damage drain tiles; result in safety hazards due to pole and guy wire placement; hinder or prevent aerial activities by planes or helicopters; interfere with moving irrigation equipment; hinder future consolidation of farm fields or subdividing land for residential development.⁷¹

To oppose these potentially diminutive effects on their land, landowners sometimes organize against them. In Ohio, a group of concerned citizens formed the group, Citizens Advocating Responsible Energy (CARE), to oppose FirstEnergy's proposed Geauga County power line. On their website they state the reasons for their opposition. They fear the HVTL will devalue the properties it crosses, force affected property owners to continue paying taxes on damaged property, damage natural beauty and local ecology, lessen agricultural productivity of impacted land, thus reducing farm income and local purchasing power, and create a thorough-fare for snowmobiles and off-road vehicles.⁷²

Other times, concerned landowners are united in voice, but not in form. In 2010, Idaho property owners in Bonneville County are nervously following the progress of Idaho Falls Power's proposed 161kV HVTL that would pass close to their homes.⁷³

Lynn Pack, a Bonneville County dairy farmer, has educated himself on HVTLs and said he's most concerned with stray voltage. "It causes so many problems with cow's production. They won't feed, they won't drink water, they dry up and when they dry up they just don't give any milk."⁷⁴ Another property owner, Sharon Nixon, fears the HVTL could harm her husband's health after his recent victory over bone cancer. She also fears the value of her home will fall. "It is not something we want in our backyard. We worked all our lives. This is our dream home."⁷⁵

Idaho Falls Power General Manager Jackie Flowers said the HVTL is a necessary step to meet new federal energy reliability standards and that the utility is open to the public's input.⁷⁶

A year earlier in Idaho, a coalition of Rockland County farmers tried to convince Idaho Power Company to avoid routing a new HVTL through their land, citing environmental and development concerns.⁷⁷ Doug Dokter, Idaho Power project leader, said the new lines are required because the existing lines are at their capacity.⁷⁸ Because of their concerns, utility representatives say they're looking at other options and hope for a compromise to avoid invoking eminent domain to take the land.⁷⁹

Sometimes opposition to a proposed HVTL route can alter its course. In 1994, Public Service Company of New Mexico abandoned plans to take new right-of-way through the Jemez Mountains for a 50-mile long HVTL extension that Indian groups and environmentalists argued would cut through several miles

71 Ibid.

72 **We oppose FirstEnergy's proposed Geauga County power line.** Website posting by Citizens Advocating Responsible Energy (CARE). Date unknown but website copyright suggests sometime from 2008-2009.

73 **Transmission Lines Worry Property Owners.** [Brett Crandall](#). Local News 8. March 5, 2010.

74 Ibid.

75 Ibid.

76 Ibid.

77 **Headway being made on proposed route for power transmission line.** Author Unknown. The Power County Press and Aberdeen Times. April 8, 2009.

78 Ibid.

79 Ibid.

of pristine vistas and Native American ruins.⁸⁰ The utility instead re-routed the extension to follow an existing utility corridor, bringing the decade-long dispute to a close.⁸¹

In 2008, California farmers and ranchers found themselves in a similar situation. San Diego Gas & Electric proposed a 150-mile long, 500kV HVTL (in conjunction with several 230kV HVTLs) across San Diego and surrounding counties to meet increasing energy needs and transport required renewable energy.⁸²

Affected landowners are worried the line will have “huge” impacts on their properties. Katie Moretti, an affected cattle rancher, and other farmers worry that building construction access roads across untouched land will limit their land’s future use. She also worries that the utility won’t compensate her for the loss of use.⁸³

Another rancher, Glen Drown, also worries about the impact the line will have on land-use and property values since the proposed route bisects several of his parcels subdivided for future development.⁸⁴

Local dairy producer, Richard Van Leeuwen, is worried that stray voltage from the line would damage the health of his calves and milking cows. To protect his herd’s health he said he would have to relocate the calf farm to another part of his property, costing millions.⁸⁵

San Diego County Farm Bureau Executive Director Eric Larson acknowledges that the farming community won’t be able to stop the project, but he’s trying to make it compatible with the area’s farming interests by recommending burying the line underground in some areas, going around some areas, and utilizing existing right-of-way.⁸⁶

Elsewhere in the state, the City of Brentwood researched the potential impact of HVTLs on agricultural land values by interviewing several of their local and experienced Real Estate brokers. All the brokers said that “Agricultural land with power lines above ground is worth less than properties with below-ground utilities.”⁸⁷

However, in a 2007 report, the California Department of Conservation’s Farmland Mapping and Monitoring Program reported that HVTLs installed on agricultural land for a wind farm will result in a temporary disturbance of 10 acres of farmland and permanently affect 1 acre. Since the affected areas are mainly grazing land, the report concluded that the HVTL would not significantly impair productivity. Though the impact to agricultural productivity during construction would be negative, they claimed it would be mostly insignificant.⁸⁸

80 **PNM Scraps Jemez Power Line Plan.** Keith Easthouse. Sante Fe New Mexican. December 16, 1994.

81 **Ibid.**

82 **Proposed power line would impact farms.** Christine Souza. California Farm Bureau Federation. May 28, 2008.

83 **Proposed power line would impact farms.** Christine Souza. California Farm Bureau Federation. May 28, 2008.

84 **Ibid.**

85 **Ibid.**

86 **Ibid.**

87 **City of Brentwood, California.** Website page explaining their approaches to valuing agricultural land. Date and author unknown.

88 **3.3 Agricultural Resources.** Part of the public draft by The California Department of Conservation’s Farmland Mapping and Monitoring Program. July 2007.

Across the country in Leesburg, Virginia, 26 landowners opposed Dominion Energy's proposed 230kV HVTL, saying it will damage their property values, thus decreasing their tax base and thus affect the county as a whole. They also fear its impact on Blue Ridge tourism.⁸⁹

Bill Hatch, owner of a 400-acre farm was upset to learn the line would run through his farm. He said the proposed line would so affect his farm that he could only afford to keep it by direct marketing or agro-tourism, but he admitted that few people would want to visit a farm with power lines.⁹⁰

Landowners want the utility to bury the lines, but the utility says it will cost 10 times more than traditional overhead lines. However, Harry Orton, an underground power line expert, testified that while the initial costs of burying the lines are higher, the lower cost of maintenance over the years evens the cost along the lines' lifecycle.⁹¹

A year later in 2006, Dominion proposed an additional 500kV HVTL to meet growing demand and routed it through northern Virginia because it was the most efficient route. However, the area is also one of the state's most pristine, and the proposal met with fierce resistance from landowners, environmentalists, Congressman Frank Wolf, and actor Robert Duvall.⁹²

In the path of the HVTL are landowners of some of the most valuable land in Virginia, and they were bothered that the utility plans to erect the 40-mile, 15-story HVTL in their back yards.⁹³

One landowner, Cameron Eaton, fears the line will bring financial ruin and "sink" her investment into her 100-acre Fauquier County property and horse business. "No one will buy that land if some ugly power line could run right over their house. I'm broken off at the knees."⁹⁴

Real estate agents consider the area's picturesque countryside to be its most valuable quality. Matt Sheedy, a land developer and president of Virginians for Sensible Energy Policy, said that the very proposal that the line will soon dominate the countryside has already "sent land values plummeting." Brokers confirmed that the market froze. People backed out of real estate contracts, unwilling to live anywhere under the line. Sheedy's groups estimated that land immediately affected could lose as much as 75% of its value.⁹⁵

"When you're out in the country and you're selling property, what you're selling is the open space and the bucolic views and the history," Sheedy said. "Running power lines through an area like this is just devastating." To landowners Gene and Deborah Bedell, who were trying to sell their 223-acre farm to pay for their retirement, it was a hard blow. Their agent told them no one would buy their property if they knew "that it could have a power line looming over it."⁹⁶

89 **Committee Hears Debate Over Underground, Overhead Power Lines.** Megan Kuhn. Leesburg Today. May 20, 2005.

90 *Ibid.*

91 **Committee Hears Debate Over Underground, Overhead Power Lines.** Megan Kuhn. Leesburg Today. May 20, 2005.

92 **Landowners Fear Ruin from Power Line Route.** Sandhya Somashekhar. Washington Post Staff Writer. December 11, 2006.

93 *Ibid.*

94 *Ibid.*

95 *Ibid.*

96 *Ibid.*

Further north in New York, over 50 landowners and local officials spoke before the state's Public Service Commission in opposition to Upstate NY Power Corp's proposed construction of a 230kV HVTL in their community.⁹⁷

Sharon B. Rossiter, co-owner of Doubledale Farms in Ellisburg, said the HVTL will damage their crop cycle, remove 100 acres from use, and make planting difficult by having to navigate around the poles. Also worried is Roberta F. French, owner of Farnham Farms in Sandy Creek. The proposed line will bisect her blueberry farm, eliminating two-thirds of it.⁹⁸

Jay M. Matteson, Jefferson County agricultural coordinator, advocated routing the HVTL through public land to avoid damaging productive, private land. "The burden should be on New York state and the developer to prove to local landowners why their land is less valuable than public land," he said.⁹⁹

The Town of Henderson opposed it because the town's foundation is tourism and agriculture, and the community is "very concerned about the visual impacts of this project."¹⁰⁰

Robert E. Ashodian, chairman of the Henderson Harbor Area Chamber of Commerce's Economic Development Committee, agreed. "The scenic resources of the community and the natural resources are at the heart of the value of the community."¹⁰¹

In an effort to appease worried or angry landowners, agricultural property owners in Montana with HVTLs encumbering their land will be exempt from paying taxes on land within 600 feet on either side of the HVTL Right-of-Way.¹⁰²

In the 2002 study, "The Impact of Transmission Lines on Property Values: Coming to Terms with Stigma," authors Peter Elliott and David Wadley cite a 1978 Canadian study that, according to one commentary, found "the per acre values from more than 1,000 agricultural property sales in Eastern Canada were 16-29% lower for properties with easements for transmission lines than for similar properties without easements." The impact was greater on smaller properties. The 1978 study found little difference in impact from 230kV or 500kV HVTLs. The study also found that the impacts didn't seem influenced by time.¹⁰³

Three more Canadian studies on the impact of HVTLs on agricultural land values found different results.¹⁰⁴ Brown 1976 studied the effect of low-voltage power lines on agricultural land in Saskatchewan and found no measurable impact on property values. The Woods Gordon 1981 study focused on the effects of 230kV to 500kV HVTLs on Ontario farmland and found some areas had an average of a 16.9% negative impact, two areas had a positive effect, and others showed no statistically

97 **Transmission line gets no support.** Nancy Madsen. Watertown Daily Times. November 17, 2009.

98 **Transmission line gets no support.** Nancy Madsen. Watertown Daily Times. November 17, 2009.

99 **Ibid.**

100 **Ibid.**

101 **Ibid.**

102 **Tax facts on proposed power line.** The Montana Standard Staff. The Montana Standard. July 11, 2009.

103 **The Impact of Transmission Lines on Property Values: Coming to Terms with Stigma.** Peter Elliott & David Wadley. Property Management, pgs.137-152. 2002.

104 **The Effects of Overhead Transmission Lines On Property Values: A Review And Analysis Of The Literature.** Edison Electric Institute Siting & Environmental Planning Task Force. 1992.

significant effect. The third study, a master's thesis referred to as Thompson 1982 found sales prices lower for properties crossed by HVTs but only where the land has potential for irrigation.(pgs. 56-57)¹⁰⁵

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¹⁰⁵ Ibid.

RESOLUTION No. PC 02-25

WHEREAS, the City of Piqua Planning Commission has reviewed the application for rezoning a newly created 5.079-acre parcel (part of the Water Treatment Plant property identified as Parcel Number N44-250148) to _____; and

WHEREAS, Parcel Number N44-250148 was annexed into the City of Piqua, Ohio in 2013 and provided an "OS" Open Space designation which permitted essential services; and

WHEREAS, no designation was provided for the parcel in 2023 as the new City of Piqua Development Code was adopted, and "OS" Open Space is no longer a valid zoning designation; and

WHEREAS, Parcel Number N44-250148 currently has the City of Piqua water plant as the only use, which is considered an Essential Service under the City of Piqua Development Code; and

WHEREAS, the Planning Commission finds that the rezoning application meets all applicable criteria and standards set forth in the City's zoning ordinance and is in the best interest of the City of Piqua.

NOW THEREFORE BE IT RESOLVED, board member _____ hereby moves to recommend _____ of the request made, as described by this resolution, the testimony provided, and the documents attached hereto, the motion is seconded by board member _____ and the voting record on this motion is hereby recorded as follows.

	AYE	NAY	ABSTAIN	ABSENT
Mr. Bradley Bubp	☐	☐	☐	☐
Mr. Eddie Harvey	☐	☐	☐	☐
Mr. Terry Wright	☐	☐	☐	☐
Mr. Adam Seas	☐	☐	☐	☐
Mr. Micah Underwood	☐	☐	☐	☐

ATTEST: _____
Clerk of Commission

_____ Chairperson

Date: _____

STAFF REPORT

Planning Commission

Date: January 14, 2025
Re: PC 04-25 – Zoning Text Amendment

Applicant: Commissioner Paul Simmons
Owner: N/A

Address: N/A
Parcel #: N/A

Zoning: N/A

Request: Recommendation for City Commission to adopt an ordinance to permit “Backyard Chickens”

Staff Comments and Recommendations:

Overview

Commissioner Simmons has submitted a proposed ordinance to allow the keeping of backyard chickens on residential lots within the City of Piqua. The ordinance outlines specific regulations regarding the number of hens, coop requirements, waste management, and penalties for violations. The intent of the ordinance is to promote self-sufficiency and provide residents the opportunity to keep chickens for personal use.

Staff Analysis:

1. Permits, Fees, and Inspections:
 - The ordinance, as proposed, does not require permits, fees, or inspections. This absence hinders the City’s ability to enforce compliance, protect residents from potential nuisances, and ensure equitable application of the regulations.
 - Without a permitting system, the City has no formal mechanism to verify adherence to the ordinance or resolve disputes effectively, potentially leading to unregulated and inconsistent implementation.
2. Zoning and Land Use Considerations:
 - The proposed ordinance does not specify whether the keeping of chickens will be permitted in all residential zoning districts or if

STAFF REPORT

restrictions apply.

- Allowing chickens in high-density residential areas or near multi-family dwellings could lead to conflicts between neighbors, particularly regarding noise, odors, and waste management.

3. Operational Challenges:

- The lack of provisions for inspection limits staff's ability to address complaints or confirm ordinance violations. This creates enforcement challenges and could increase neighbor disputes.
- Excluding fees eliminates potential funding to support administration and oversight of the program, placing additional financial and operational burdens on City staff.

4. Community Impact:

- While the ordinance aims to support personal freedom and self-sufficiency, it may inadvertently lead to negative externalities, including nuisance complaints, public health concerns, and strained neighbor relations.
- The absence of visual barrier requirements could exacerbate tensions, as coops and associated activities may detract from the aesthetics of neighboring properties.

5. Precedent and Comparative Analysis:

- Other communities that allow backyard chickens often implement permits, fees, inspections, and zoning restrictions to balance resident interests and ensure program success.
- The proposed ordinance lacks these standard regulatory measures, which could result in challenges unique to Piqua.

§ 90.03 ABANDONMENT; ANIMALS RUNNING AT LARGE. PROHIBITED ACTS AND NUISANCE CONDITIONS

(A) (1) No owner of a dog, cat, or other domestic animal shall abandon the animal.

(2) Except as otherwise provided in § 90.05(B), no owner of horses, mules, cattle, sheep, goats, swine, dogs, geese or other fowl, or animals shall permit them to run at large upon any public way or upon the land of another.

(‘97 Code, § 91.03)

(B) It shall be unlawful for the owner of any animal to allow the same on the lands of the Echo Hills Golf Course.

(‘97 Code, § 91.22) Penalty, see § 90.99

(C) (1) No owner shall allow his or her dog, cat or other domestic animal to become a public nuisance. Excessive barking, whining or howling, molesting passers-by, chasing vehicles, attacking other domestic animals, and damaging property shall be considered a nuisance under this section.

(2) The owner or person in charge or control of any animal which scratches, digs, urinates or defecates upon any lawn, tree, shrub, plant, building or any other public or private property (other than the property of the owner of the animal) shall immediately repair any damage and remove all feces deposited by the animal and dispose of same in a sanitary manner.

(‘97 Code, § 91.06)

§ 90.05 NUISANCE CONDITIONS. PROHIBITED LIVESTOCK ANIMALS

~~—(A) (1) No owner shall allow his or her dog, cat or other domestic animal to become a public nuisance. Excessive barking, whining or howling, molesting passers-by, chasing vehicles, attacking other domestic animals, and damaging property shall be considered a nuisance under this section.~~

~~—(2) The owner or person in charge or control of any animal which scratches, digs, urinates or defecates upon any lawn, tree, shrub, plant, building or any other public or private property (other than the property of the owner of the animal) shall immediately repair any damage and remove all feces deposited by the animal and dispose of same in a sanitary manner.~~

~~(‘97 Code, § 91.06)~~

—(B) (A) (1) It shall be unlawful and considered a public nuisance for any person to own, keep, harbor or maintain any ~~agricultural animal~~ restricted agricultural animal on any parcel of land less than five acres in size or within 1,000 feet of any residence other than his or her own.

(2) For the purpose of this section, ~~AGRICULTURAL ANIMALS~~ “restricted agricultural animals” include horses, mules, donkeys, ponies, cattle, swine, sheep, goats, geese, ducks, turkeys, guinea fowl, roosters, and peacocks, ~~and chickens.~~

(3) Nothing in this section shall be construed to prohibit the following:

- (a) The feeding of ducks and geese at Echo Lake;
- (b) The temporary custody of agricultural animals by a licensed veterinarian;
- (c) The temporary custody of agricultural animals by a food processing businesses;
- (d) The temporary custody of agricultural animals not exceeding three consecutive days per calendar year by any person, firm, corporation or association sponsoring any charitable, promotional, civic or other civic or special event, festival, celebration or fund-raising activity, subject to approval by the ~~Public Works~~ Community Services Director or his/her designee at least seven days in advance; or
- (e) The custody of agricultural animals by educational institutions.

(‘97 Code, § 91.20) Penalty, see § 90.99

§ 90.07 PENS FOR RABBITS STANDARDS FOR LIVESTOCK ANIMALS

(A) Rabbits.

- (1) Any person, persons, firm, or corporation who owns, keeps or harbors three or more rabbits on any premises within the corporation limits of the city must keep the same in a building or structure used exclusively for that purpose, and which building or structure shall be located 75 feet or more from any other building, house, or structure which is used for human occupancy or habitation, or where food is sold, served, or otherwise handled. The building or structure must have a ceiling of not less than seven feet in height from the floor, at any point, with sufficient windows and opening to furnish light to all points of the building or structure. Ventilation shall be sufficient so as to furnish six complete changes of air per hour, and all openings must be fully screened so as to keep out flies and other insects. The floor of the building or structure must be of concrete and free from flaws or cracks, and graded and sloped so that the floor will properly drain to a floor drain, which is to be connected to a sanitary sewer and vented. The foundation of the building or structure must be of a height of not less than six inches above the floor level, or have a cement baseboard at least six inches in height.
- (2) The hutches, cages, or pens in which the rabbits are kept or harbored must be at least 16 inches in height, 30 inches in width, and 40 inches long. Hutches, cages, or pens shall not be placed or erected on top of each other over three hutches in height. Hutches may have a steel or wood frame. The top and sides must be covered with galvanized wire netting and a -inch mesh

- galvanized wire floor, with a watertight galvanized iron drip pan of not less than 16-gauge, and shall be large and sufficient enough to catch all drippings and waste. The drip pans shall be at least one inch deep and placed two or more inches under each floor of each hutch, and arranged, built, and erected so that the pans can be taken out for cleaning and flushing. The hutches must be erected so that they will stand away from any wall, and have an aisle of at least four feet in width between the rows of same.
- (3) The hutches must also have a proper feed rack and chaff pan for same, but they must be built and erected double, end to end, so one rack and pan can provide for both hutches. Drip pans and floor must be washed, flushed, and disinfected every day from April 1 to October 30, inclusive, of each year, and for the balance of each year the drip pans and floor must be washed, flushed, and disinfected at least every other day. The waste and manure must be kept in tight metal containers with tight and well-fitting lids and disposed of at reasonable intervals. The floor of the building or structure shall be kept free from all obstructions at all times so that it can be easily and readily flushed.
 - (4) Each hutch, cage, or pen shall contain at any one time not more than one rabbit over six months of age except a doe and litter until the litter reaches six weeks of age.

(B) Chickens.

(1) Person(s) dwelling in a single-family residential property may raise chickens on the premises pursuant to the following terms and conditions.

(a) Permit. Any person who keeps chickens within the City shall obtain a permit from the Community Services Department prior to acquiring the chickens.

1. Fee: A fee will be set within the fee schedule for a permit and may be increased over time at a maximum of 5% annually to accommodate increased costs. The initial fee will be \$10.00.
2. Validity: A permit shall be valid for one (1) year from the date of approval and must be reapproved annually.
3. Inspection: An inspection shall occur within ten (10) days of the issuance of a permit by the city confirming all requirements are met.
4. Proof of Veterinarian: Proof that person(s) requesting a permit have a veterinarian that may be utilized for their chickens.

(b) Standards.

1. The property must have the minimum dimensions required to fulfill the standards of this section.
2. No more than six (6) chickens may be kept on any lot.
3. No roosters may be raised or kept on the property.
4. No slaughter of chickens may take place on the property.
5. No person shall sell eggs obtained from their chickens at their residence. Home occupations approved under the Development

Code shall meet all applicable State and Local Health Department Regulations.

6. Chickens must be provided with an elevated, covered enclosure, and the chickens must be kept in the enclosure. The enclosure must be well-ventilated, dry and clean. Outdoor runs are prohibited.
7. Enclosures used for the keeping of chickens are allowed in the rear yard only. See Chapter 154 for yard definitions.
8. Enclosures must have a solid visual barrier surrounding them, such as an opaque privacy fence or mature landscape screening. Enclosures shall be screened in manner so the structure is not visible from the public right of way or any adjoining properties.
9. No enclosure may be located closer to ten (10) feet from any property line and no closer than twenty-five (25) feet from any adjacent residential structure designed for human occupancy.
10. All enclosures for raising chickens must be constructed and maintained to prevent infestation of rodents or pests.
11. All feed and other items associated with the raising of chickens must be protected to prevent rodents and pests from gaining access or coming into contact with them by being stored in rodent-proof containers. Storage containers shall be subject to the same location, setback and screening requirements as the enclosures.
12. Waste associated with raising chickens must be disposed of by being bagged separately and removed from the premises by a trash collection service not less than once per week. No waste associated with raising or keeping chickens may be used as compost or otherwise disposed of by means other than removal of the waste from the premises.

(C) Notwithstanding any other provision of this chapter, participants in projects sponsored by 4-H Club or similar organizations may apply for exemptions from one or more restrictions contained in § 90.04(A), provided:

(1) The participant establishes his or her bona fide and current affiliation with the 4-H Club or similar organization to the satisfaction of the Health and Sanitation Officer.

(2) The participant submits a comprehensive and written description of his or her proposed project, satisfactory to the city Health and Sanitation Officer (which shall in no event provide for keeping more than 24 rabbits).

(3) The participant maintains and fulfills the project in complete conformity with his or her written description satisfactory to the Health and Sanitation Officer.

(‘97 Code, § 91.18) Penalty, see § 90.99

(D) A violation of this section constitutes a misdemeanor of the first degree.

RESOLUTION No. PC 04-25

WHEREAS, a proposal regarding the regulation of backyard chickens has been submitted by a City Commissioner for review; and

WHEREAS, after careful consideration, the Planning Commission finds that the proposed ordinance can be supported with the inclusion of the following amendments:

1. Permits and Fees – Require an annual permit with a nominal fee to ensure compliance and fund program administration.
2. Inspections – Incorporate language allowing City staff to inspect properties with permits to verify compliance and address complaints effectively.
3. Zoning Restrictions – Limit backyard chickens to specific residential zones and prohibit them on commercial properties or rental units without owner approval.
4. Visual Barriers – Require screening or fencing to minimize aesthetic impacts and enhance neighborhood compatibility.

NOW, THEREFORE, BE IT RESOLVED that the Planning Commission hereby approves the proposed ordinance regarding backyard chickens, contingent upon the above-mentioned amendments being incorporated into the ordinance.

NOW THEREFORE BE IT RESOLVED, board member _____ hereby moves to recommend _____ of the request made, as described by this resolution, the testimony provided, and the documents attached hereto, the motion is seconded by board member _____ and the voting record on this motion is hereby recorded as follows.

	AYE	NAY	ABSTAIN	ABSENT
Mr. Bradley Bubp	☐	☐	☐	☐
Mr. Eddie Harvey	☐	☐	☐	☐
Mr. Terry Wright	☐	☐	☐	☐
Mr. Adam Seas	☐	☐	☐	☐
Mr. Micah Underwood	☐	☐	☐	☐

ATTEST: _____
Clerk of Commission

_____ Chairperson

Date: _____