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Letter

HistoricalRedliningIsAssociatedwithPresent-DayAirPollution DisparitiesinU.S.Cities

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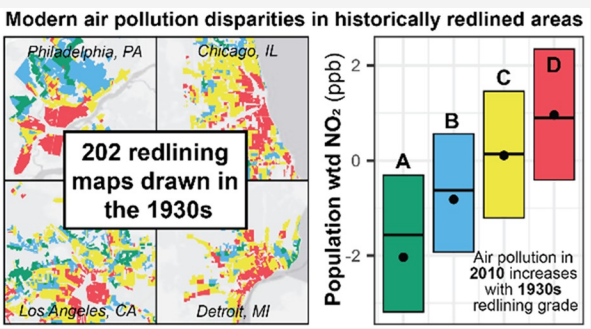
ABSTRACT:CommunitiesofcolorintheUnitedStatesare systematicallyexposedtohigherlevelsofairpollution.Weexplore herehowredlining,adiscriminatorymortgageappraisalpracticefrom the1930sbythefederalHomeOwners'LoanCorporation(HOLC), relatestopresent-dayintraurbanairpollutiondisparitiesin202U.S. cities.Ineachcity,weintegratedthreesourcesofdata: (1)detailed HOLC security maps of investment risk grades [A ("best"), B, C, and D ("hazardous",i.e.,redlined)], (2)year-2010estimatesof$NO_2$and $PM_{2.5}$airpollutionlevels,and(3)demographicinformationfrom the 2010U.S.census.Wefindthatpollutionlevelshaveaconsistentand nearlymonotonicassociationwithHOLCgrade,withespecially pronounced(>50%)increments in NO_2 levels between the most (grade A) and least (grade D) preferentially graded neighborhoods. On a national basis, intraurban disparities for NO_2 and $PM_{2.5}$ are substantially larger by historical HOLC grade than they are by race and ethnicity. However, within each HOLC grade, racial and ethnic air pollution exposure disparities persist, indicating that redlining was only one of the many racially discriminatory policies that impacted communities. Our findings illustrate how redlining, a nearly 80-year-old racially discriminatory policy, continues to shape systemic environmental exposure disparities in the United States.



KEYWORDS:airpollution,redlining,NO_2,$PM_{2.5}$

INTRODUCTION

In the United States, communities of color are exposed to lower levels of air pollution at every income level.[1−4] As with other environmental justice (EJ) issues, the causes of systemic racial/ethnic air pollution exposure disparities are complex and rooted in part in historical patterns of exclusion and discrimination. While air quality has improved in the United States over the past several decades,[5−7] people of color (POC), particularly Black and Hispanic Americans, are still exposed to higher-than-average levels of air pollution.[8−11] We examine here how redlining, a historical, racially discriminatory 1930s

Redlininghasemergedasanareaofinterestbecauseitis welldocumentedandwasexplicitinitsdiscriminatory implementation,widespread,andcarriedoutbythefederal government.Beginninginthe1930s,thefederallysponsored HomeOwners'LoanCorporation(HOLC)drewmaps characterizingneighborhoodsecurityforemergencyhome lending for several hundred U.S. cities in the wake of the Great Depression.[23,24] These maps, which are digitized for 202 U.S. cities,[25] graded neighborhoods on a four-point scale: A (most desirable), B (still desirable), C (definitely declining), and D (hazardous, i.e., redlined). Many neighborhoods received the worst grade due to the presence of Black and immigrant communities and/or known environmental pollution sources.[25,26] For example, racist language provided to HOLC agents describes "infiltration of foreign-born, Negro, or lower-grade population" as cause for a lower neighborhood grade.[25] Homes in D neighborhoods were typically ineligible for

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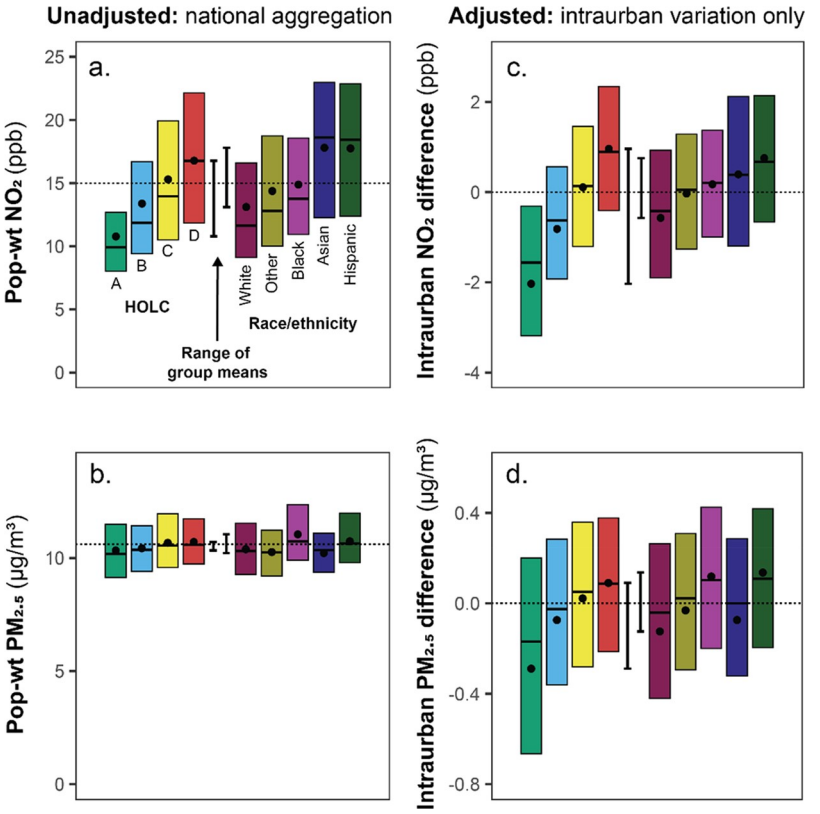

Figure 1. Population-weighted distributions of NO_2 and $PM_{2.5}$ levels within HOLC-mapped areas at the census block level. Bars represent 25th and 75thpercentiles.Mediansareindicatedwithhorizontallines,andmeansbythedotmarker;theoverallmeanisindicatedbythedottedline. Unadjustednationaldistributionsarepresentedfor(a)$NO_2$and(b)$PM_{2.5}$.Adjusteddistributions(candd)reportthenationaldistributionsof intraurbandifferencesforcensusblockswithinagivenHOLCgraderelativetothePWMlevelwithineachcity.Ineachpanel,pollutionlevel distributionsarereportedbybothHOLCgrade(leftcluster)andrace/ethnicity(rightcluster).Verticallinesbetweentheseclustersreflectth e pollution range of the group means: the difference in the population-weighted mean between groups A and D (left line) and between the highest-exposedandlowest-exposedracial/ethnicgroup.Panelscanddillustratehowintraurbandisparitiesareconsistentlyhigherbyhi storicalHOLC gradethanbyrace/ethnicity.

practiceisolatedcommunitiesofcolor,restrictingtheirability tobuildwealththroughhomeownership,andinformedlater localgovernmentlandusedecisionsthatplacedhazardous industriesin andnearDneighborhoods.[24]Thediscriminatory practicescapturedbytheHOLCmapscontinueduntil1968, whentheFairHousingActbannedracialdiscriminationin housing,yetthelegacyofexplicitracialdiscriminationstill shapespatternsofracialresidentialsegregationtoday.[27] Agrowingbodyofscholarshipfindsassociationsbetween redliningandpresent-dayenvironmentalhealthdisparitiesin U.S.cities.Forexample,in64%ofgradeDneighborhoods,a majority(>50%)ofthepopulationisPOC(i.e.,notnon-HispanicWhite);in74%ofgradeDneighborhoods,the medianincomeislowtomoderate.[27]Redliningdesignations are associated with a variety of exposures, including greenspace prevalence,[28]treecanopy,[29−31]urban-heatexposuredispar-ities,[29,32,33]andhealtheffects,includingasthma,[34]cancer,[35,36] adversebirthoutcomes,[37,38]andoverallurbanhealth.[39]To date,limitedresearchhasinvestigatedairpollutionexposure andredlining,[31,34]despiteitsimportanceasanenvironmental riskfactor.

Wefocushereontwokeyairpollutantsthataresignificant causesofillhealthandprematuremortality,nitrogendioxide (NO_2)andfineparticulatematter($PM_{2.5}$),andhavedistinct sources,atmosphericbehavior,andspatialpatterns.NO_2isa relativelyshort-lived,localizedpollutantemittedbytraffic,

best;B,stilldesirable;C,definitelydeclining;orD,hazardous formortgageappraisal.WelinkedHOLCmapstoindividual U.S.Censusblocksfromthemostrecentavailabledecennial census(2010);[48]censusblocksprovideaspatialresolutiona t approximatelythescaleofacityblockinurbanareas (geospatialproceduresaredescribedinthe).Theresultingd atasetincorporates45million peoplein202U.S.cities(n=562,078censusblocks;average populationof80peopleperblock).

Becauseofurbanexpansionpost-1930,theHOLCareas representonlyasubsetoftheoverallpresent-dayurban footprintinmostmetropolitanareas:thepresent-dayurban core.Toprovidecontextandcomparison,wealsoseparately extendouranalysistothefullU.S.Censusurbanizedareas (CUA;n=148)thatcontaintheHOLC-mappedneighbor-hoods.These148CUAshadayear-2010populationof161 millionpeople(∼65%ofthefullU.S.populationresidingin urbanizedareasin2010).

Wecombinerace/ethnicitydatatodevelopfouraggregate groupingsforanalysis:peoplewhoareHispanicofanyrace [24%ofHOLCpopulation()],non-HispanicWhite (henceforthWhite,43%),non-HispanicBlack(Black,23%), and non-Hispanic Asian (Asian, 7%). The remaining 3% of the HOLCpopulation(Other)includesPacificIslander,Native American, and populations self-identifying as belonging to two or more races. The broader CUA population demographics are asfollows:56%White,15%Black,7%Asian,and19% Hispanic.

AirPollutionData.WecharacterizedNO$_2$andPM$_{2.5}$ levelsusingempirical(i.e.,land-useregression)models developed by the Center for Air, Climate and Energy Solutions (CACES;).[5]Thisdatasetprovidesannual ambient concentration predictions for census blocks for 1979−2015.Weemployyear-2010pollutiondataheretoalignwith the most recent available (2010) decennial census. This model surfaceanditspredecessorsarecommonlyusedfordisparit y analyses[1,2,49]andpredictNO$_2$andPM$_{2.5}$atU.S.EPA monitoringsiteswithhighfidelity(R^2=0.81and0.84, respectively).[1]Ourcoreresultsareexpressedaspopulation-weightedstatistics[i.e.,population-weightedmean(PWM) andotherpercentilesfromthepopulationdistributionof exposures].

We first aggregate data in terms of unadjusted statistics (e.g., the national PWM concentration for all blocks in the D grade). Next,toisolateassociationsbetweenredliningandintraurba n gradients,wepresentadjustedstatisticsthatholdconstantfo r city-to-city differences in air pollution and therefore reveal only within-urbandisparities.Thisadjustedstatisticiscomputedas thenationalPWMoftheintraurbanconcentrationdifference, i.e.,thedifferencebetweencensusblocklevelsandthe correspondingurbanPWMacrossallHOLCareasinaCUA (see).Anexample of the input data sets for Atlanta, GA, is included in, andpopulationdemographicsareoutlinedin.

RESULTSANDDISCUSSION

AssociationsbetweenConcentrationandHOLC Category.BecauseHOLC-mappedareastendtocoveronly citycentersandexcludesuburbanareas,airpollutionlevelsin theHOLC-mappedareastendtobehigherthaninthe correspondingoverallCUAs().Year-2010PWM concentrations were 15.0 ppb (NO_2) and 10.6 μg m^{-3}($PM_{2.5}$)

DisparitiesbyRace/Ethnicity.Wefurtherstratifiedour resultsbycomparingeachHOLC-gradePWMconcentration forindividualracial/ethnicgroups.Consistentwiththe substantialliteratureonracial/ethnicdisparitiesforair pollution,wefindthatpeopleofcolorexperiencehigher-than-averageNO2andPM2.5levelsandareoverrepresented within C and D neighborhoods, consistent with prior redlining research (Figure 1). For example, on average, PWM intraurban pollutiondifferencesforNO2(Figure1c)aregreaterthan averageforHispanic,Asian,andBlackpopulations(0.8,0.4, and0.2ppbhigherthantheurbanaverage,respectively)and belowaveragefortheWhitepopulation(−0.6ppb). DifferencesforPM2.5areproportionallysmaller(Figure1d) but reflect similar racial disparities (PWMs of −0.1 μg m−3for WhiteandAsianpopulationsand0.1μgm−3forBlackand Hispanicpopulations).Overall,intraurbanPWMdifferences byHOLCgradearelargerthanbyrace/ethnicity(Figure1). We find a substantially larger PWM differences between D and AHOLCgrades(3.0ppbNO2and0.4μgm−3PM2.5)than between the most- and least-exposed racial/ethnic groups [1.3 ppbNO2and0.26μgm−3PM2.5(seeFigure1c,d)].

Next,weexaminedhowracial/ethnicdisparitiesinteract withhistoricalHOLCgrade.Figure2illustratesPWM

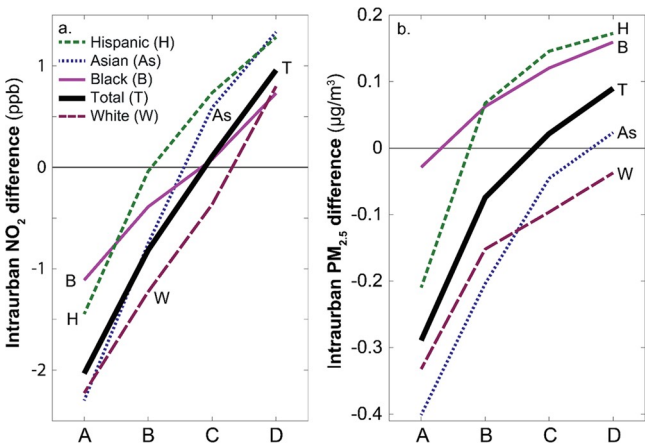

Figure2.Population-weightedmeanannualintraurbanPWMlevels byHOLCgradeandrace/ethnicityfor(a)NO2and(b)PM2.5.All race/ethnicitygroupsdemonstratemonotonicincreasesbyHOLC grade.DisparitiesbyHOLCgradewerelargerthanthoseassociated withdifferencesbetweenracial/ethnicgroups(100%higherforNO2 and50%higherforPM2.5).

intraurbandisparitiesthatexistbyrace/ethnicityalongthe A−DHOLCgradegradient.Smaller,butstillsubstantial, intraurbanracial/ethnicdisparitiesexistforPM2.5andNO2 withineachhistoricalHOLCgrade.Onaverage,thewithin-grade white population experiences lower than average levels of NO2andPM2.5whiletheHispanicpopulationexperiences aboveaveragelevels.TheBlackpopulationexperiences consistentlyaboveHOLC-grade-averagePM2.5levelswhile theAsianpopulationexperiencesaboveHOLC-grade-average NO2 levels. These within-grade disparities are nearly as large as the overall racial/ethnic disparity for the HOLC-mapped areas, implyingthatasubstantialportionoftheracial/ethnic exposuredisparitywithinthestudyareasexistsindependentl y ofhistoricalHOLCstatus.

Racial/ethnicairpollutiondisparitiesreportedhereare subdividednextintotwodistincteffects:thosethatare associatedwithhistoricalHOLCredliningandthosethatare

Detaileddescriptionofmaterialsandmethods,supporting demographictables,andsupportingfiguresS1−S11 ()

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