NIP24
IMAGE PERMANENCE
Accuracy in Photo Print Life Prediction

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RESEARCH

IMAGE PERMANENCE CONCERNS

Origins

- Early color photography materials were unstable
- Images changed noticeably over time
- The rise of color photography as art
- Image instability devalued galleries assets
- Early research showed stability affected by various exposure conditions
- Galleries now optimize environments as well as exposure and storage conditions
- Acceptable prints from inkjet gave rise to competition with silver halide
- Image permanence differences became a marketing issue
- Consumer awareness developed

PHOTOS

Consumer Expectations

- Cost
- Visual Quality
- Portability
- Convenience
- Stability
- Durability


PHOTOS
Image Content and Quality Variability

THE SIMPLICITY OF THE GOAL

Tell users that their print will last a certain number of years

And they will believe you

(After all, the EPA reports what mileage we will get)

PRINT LIFE PREDICTIONS

The Complexity of the Task

- **Various exposure factors are known to affect print life**
  - **Light exposure**
  - **Air pollution exposure**
  - **Temperature exposure**
  - **Humidity exposure**
- **Print usage factors also affect life**
  - **Geographic location**
  - **Display location**
  - **Display filters**
  - **Storage conditions**
  - **User perception of failure**

PHOTOS

Stability Reality

- Life is NOT independent of exposure conditions
  - We know that but the consumer does not
  - Marketing information is misleading
- Life is dependent upon a complex interaction of a number of exposure factors on the image materials
- Actual life WILL vary depending upon these factors
- Different technologies have different stability performance
- Different systems within a technology have different stability performance
- Is "*Individual results may vary*" a reasonable disclaimer?

STABILITY PREDICTION MODELS

- **Real time testing to prove stability is impractical**
- **Accelerated testing using predictive models is generally accepted**

  1 year at 100klux = 200 years at 500 lux*

  *Where 500 lux might be the 'normal real world exposure factor'

- **Reciprocity failure is taken into account where known**

  BUT

- **Testing is carried out under single exposure condition with all other factors eliminated or minimized**
  - **Light fade testing is completed with 0 pollutant exposure and at nominal temperature and humidity**

ISSUES WITH PREDICTIONS

- What is a ‘real world’ exposure factor?
- How well can one exposure factor be used for everyone?
- Do the test methods adequately replicate reality?
- How well have reciprocity effects been quantified?
- Is there a synergistic behavior when more than one agent is present?
- Do the predictions adequately inform the consumer?

PREDICTIVE EXPOSURE FACTORS

- **Factors that are proposed for use in predicting print life based on accelerated ageing tests for the two most often reported exposure conditions**

Condition	Accelerated Level	Assumed Consumer Level
Light	35 kLux	250 lux (12 hr/day)
Ozone	1 ppm	9 ppb

- **How well do these factors reflect the real world?**

REAL WORLD EXPOSURE

Formal Study on Light Exposure

- **Only one large scale world wide test has been reported so far**
- **Indoor level on wall hung photos in 8 homes in each city**
- **Study conducted in each location measuring exposure for several months**

City	Mean (lux)	90th Percentile (lux	95th Percentile (lux)	99th Percentile (lux)
Rochester	62	151	218	431
Los Angeles	71.5	140	177	312
Atlanta	19.6	46.1	66.9	109
London	76.1	151	208	964
Melbourne	93.7	211	343	617
Shanghai	59.1	156	227	469
Average >		**136**	**211**	**540**

REAL WORLD EXPOSURE

Informal Study on Exposure Uniformity

- Measurements of display prints on office walls
- Torrey Pines Research Fairport NY office
- There are a total of 28 digital images on the walls.
- The illumination in the center of the images at 3pm in January
  - Measured from 19 lux to 535 lux, depending on where that particular image is hung. The mean of these measurements is 93 lux
- Image in conference room maps at 31, 35, 94, 95, and 44 lux based on measurements at the top left, top right, bottom left, bottom right and center respectively
- Another image in a corridor near an outside glass door measures 45, 11, 100, 280 and 163 lux respectively

REAL WORLD EXPOSURE

Implications of the Real World Light Exposures

- **FORMAL MEASUREMENTS**
  - Variation in exposure level depending upon geography was at least 3:1
  - Proposed factor (250 lux) is close to 95th percentile of measured exposure. Which percentile should be used?
- **ANECDOTAL MEASUREMENTS**
  - Variation in exposure level depending upon location in a facility was at least 20:1
  - Variation in exposure level over a single print could be as high as 25:1
- **IMPLICATION**
  - Use of a single exposure factor for life prediction in finite years is unscientific and misleads consumers

REAL WORLD EXPOSURE

Ozone Exposure Measurements - USA

- **US EPA published measurement of mean ozone levels by city**

City	2006 Outdoor	2006 Est. Indoor*	
	Mean Levels ppb	No A/C	With A/C
Atlanta, GA	51	21	16
Houston, TX	49	20	16
Los Angeles, CA	37	15	12
New York, NY	42	17	13
Salt Lake City, UT	57	23	18
San Jose, CA	37	15	12

* Cass, Druzik et al, Protection of Works of Art from Atmospheric Ozone. (The Getty Conservation Institute – Research in Conservation) 1989

REAL WORLD EXPOSURE

Ozone Exposure Measurements - Europe

- **Outdoor ozone levels in ppb**
- **Based on measurements in 25 to 35 countries (increases by year)**

	1999	2000	2001	2002	2003	2004	2005	2006
avg	25	24	25	27	27	25	25	27
min	10	11	8	19	13	18	16	18
max	31	31	30	51	44	36	37	38

REAL WORLD EXPOSURE

Ozone Exposure Measurement Variations Indoors

Location		Ratio Reported By:			
		US EPA	SR Hayes	Ilford	Canon
Outdoor		1	1	1	1
Home	Windows open	0.41	0.65		
	Windows closed		0.36	0.04 - 0.19	0.1 - 0.3
	Air conditioned	0.31	0.23		
Office	AC supplying outside air		0.82	0.6 - 0.85	
	Typical AC		0.6		

- **The Good News**
  - **Real world indoor levels are lower than outdoor levels**
- **The Bad News**
  - **Variation indoors can be as high as 20:1**

REAL WORLD EXPOSURE

Implications of the Real World Ozone Exposures

- **IN HOME VARIATIONS**
  - Indoor/outdoor factors vary widely and must be regarded as tentative
  - Even so, it is likely that variation in exposure level in homes is in the range 10:1 to 20:1
- **GEOGRAPHIC VARIATIONS**
  - Variation in exposure level of 2:1
  - Proposed factor (9ppb) is close to 75th percentile of calculated average indoor exposure. Which percentile should be used?
- **EXPOSURE FACTOR**
  - Use of a single exposure factor for life prediction in finite years is unscientific and misleads consumers
  - Proposed ozone exposure factor (75th) for predictions is inconsistent with light exposure factor (95th)

TESTING METHODS

Accelerated Aging – Light Exposure

- Attempt to replicate consumer exposure but at accelerated rate
- Spectral energy as close to sunlight as possible
- Glass filter used (replicates framed print)
- Tests completed at controlled T&H and no ozone
- Reciprocity measurement not required based on many reports

- REAL WORLD EXPOSURE
  - Likely to be a combination of sunlight and tungsten with an increasing level of fluorescent
  - Will expose light and ozone simultaneously

TESTING METHODS

Accelerated Aging – Ozone Exposure

- Attempt to replicate consumer exposure but at accelerated rate
- Tests completed at controlled T&H and no light
- Reciprocity measurement not required
  - In spite of recent evidence of reciprocity failures

- REAL WORLD EXPOSURE
  - Typical wall hung prints will have a microclimate
  - Will expose light and ozone simultaneously

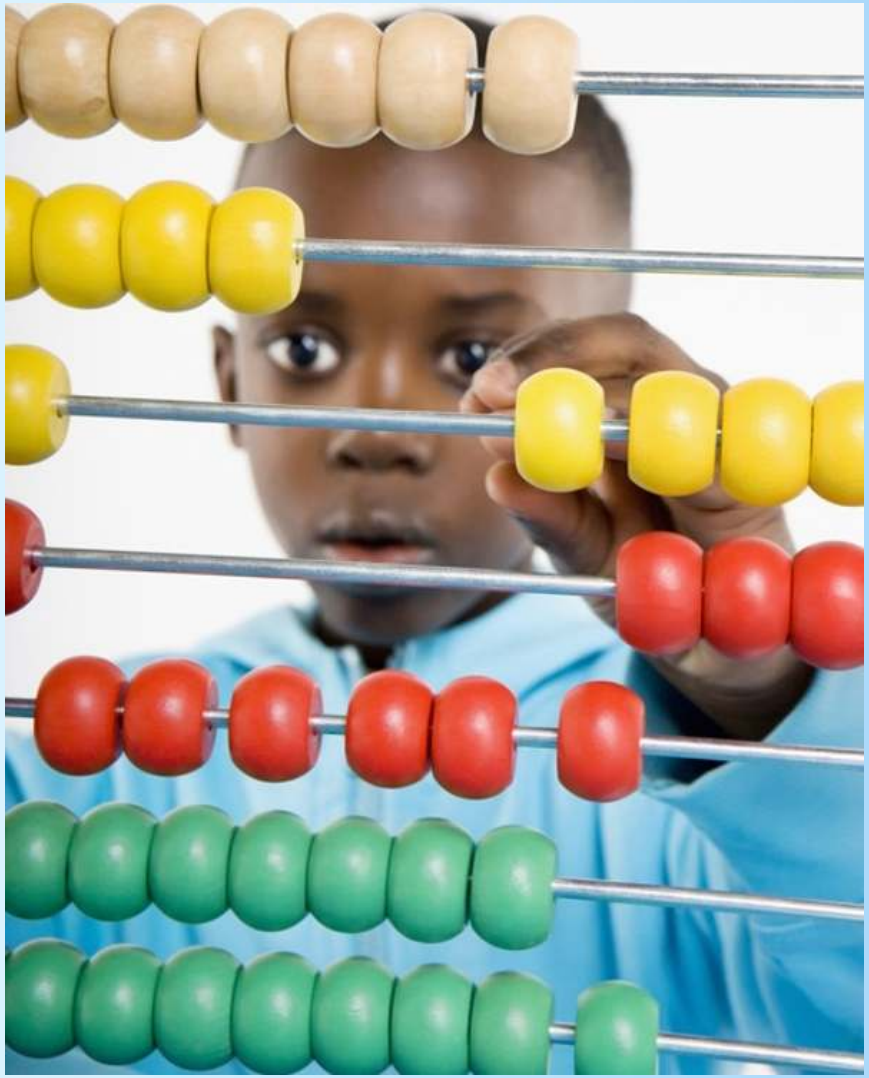
TESTING METHODS

Endpoints

- When has the test image failed?
- Proposal is based on a shift of 0.3 density units in a given patch
- This is always related to the original untested image

TESTING METHODS

Endpoints - Is this image acceptable?



TESTING METHODS

Endpoints - Is this image acceptable?

TESTING METHODS

Endpoints - This is the original

TESTING METHODS

Endpoints

- Many studies have shown that consumers are more sensitive to 'just noticeable' changes as assessed by colorimetric measures
- Even just noticeable changes relate to comparison with original image
- Consumers rarely compare to an original image
- Endpoints may be too conservative

TESTING METHODS

Implications of the Testing Methods

- Poor simulation of real world combined light sources may affect accuracy of light exposure prediction
- Ignoring the effect of microclimates may affect accuracy of light and ozone exposure predictions
- Ozone reciprocity effects may lead to inaccurate prediction
- Synergy between exposure factors may reduce real life of print
- Endpoints are likely to be too conservative resulting in under-predicting life

PREDICTION METHODS

The Light and Ozone Calculations

- **Light Fade Exposure**
  - Calculation assumes a 12 hour day with 0 exposure for the other 12 hours
  - Life (yrs) = (lux days)*2/(250*365)
  - E.g. a sample that reached an endpoint after being exposed to 35 kLux for 130 days would reach the same endpoint after 100 years of 250 lux per day 12 hour days exposure
- **Ozone Exposure**
  - Life (yrs) = (ppb days)/(9*365)
  - E.g. a sample that reached an endpoint after being exposed to 1ppm ozone for 328 days would reach the same endpoint after 100 years of 24 hour/day exposure to 9ppb ozone

PREDICTION METHODS

The Same Calculations with Real World Values

Light Fade: ~4:1 variation in life predictions

Exposure		Exposure level (lux)	Predicted Life (Years)
World houses	95th percentile	250	100
World houses	75th percentile	100	250
World houses	Mean exposure	64	390
TPR	Office wall	93	268

Gas Fade: ~13:1 variation in life predictions

Exposure		Exposure level (ppb)	Predicted Life (Years)
Proposed (ref)	Indoor	9	100
Southern Cal	95th percentile indoor	41	22
*Switzerland	Indoor well vented	21	43
*Switzerland	Indoor poorly vented	3	300

*Real Life Indoor Permanence of Inkjet Prints in Correlation with Accelerated Ozone Fading and Light Fastness Testing. Reber, Hofman. European Coating Conf 2006

PREDICTION METHODS

Neglected Factors

- **Storage conditions**
  - Photos in shoeboxes and albums
  - Light and air stagnant or excluded
  - Orders of magnitude less fade
  - Orders of magnitude greater life
- **Display Microclimates**
- **Effects of other pollutants NO_x, SO_x**
  - Known to affect fade (+ and -)
  - Atmospheric levels not well reported
- **Test lab procedures**

PREDICTION ACCURACY

Summary of the Problem

- **VARIATIONS IN LIFE PREDICTION ACCURACY**
  - Real world light variables ~ at least 4:1 range
  - Real world ozone variables ~ at least 13:1 range
  - Real world storage conditions ~ orders of magnitude range
  - Pollutant increases over time ~ at least 2:1 range
  - Endpoint variables - ?
  - Test method variables - ?
  - Other factors - ?

- **WORST CASE IS A VARIATION OF ABOUT 50:1**

- **BASED ON THIS, IS THIS STATEMENT MISLEADING?**
  - Print Life 100 years ("*Individual results may vary*")

PREDICTION ACCURACY

What a scientifically accurate Light Fade Prediction SHOULD include

100 YEAR LIGHT EXPOSURE PRINT LIFE

- Measurement and method errors could make it 60 to 140 years
- On an individual print you may be satisfied for a longer time
- In New York City, but not in other cities or countries
- With much lower than average ozone levels
- Provided global ozone levels do not increase
- Print hung on an inside wall with indirect sunlight
- Not hung near an outside doorway
- Air conditioned

PREDICTION ACCURACY

How can it be Improved?

- Add this kind of detail to the reporting
  - Not enough room on packages, confuses consumers
- Add error bars to the predictions
  - Bars would be of the same order as values
- Report display life vs storage life
- Complete more worldwide tests and get better data
  - Appears likely that this would result in even larger variations
- ISO committees have been deliberating for many years with no standard in sight

AN ALTERNATIVE

Report Results, not Predictions

- Predicting the future is not the business of scientists
- EPA Mileage Tests not a good comparison
- EPA does not try to predict your auto's life in miles
- Relative resistance to fade is what is being measured and should be reported as such
- Simple numeric or alpha scale
- One value for light, one for ozone etc
- Reserve life prediction for examples

TORREY PINES

RESEARCH

THANK YOU