A robust sebum, oil, and particulate pollution model for assessing cleansing efficacy of human skin

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Abstract
With increasing concerns over the rise of atmospheric particulate pollution globally and its impact on systemic health and skin ageing, we have developed a pollution model to mimic particulate matter trapped in sebum and oils creating a robust (difficult to remove) surrogate for dirty, polluted skin.

OBJECTIVE: To evaluate the cleansing efficacy/protective effect of a sonic brush vs. manual cleansing against particulate pollution (trapped in grease/oil typical of human sebum).

METHODS: The pollution model (Sebollution; sebum pollution model; SPM) consists of atmospheric particulate matter/pollution combined with grease/oils typical of human sebum. Twenty subjects between the ages of 18–65 were enrolled in a single-centre, cleansing study comparisons between the sonic cleansing brush (normal speed) compared to manual cleansing. Equal amount of SPM was applied to the centre of each cheek (left and right). Method of cleansing (sonic vs. manual) was randomized to the side of the face (left or right) for each subject. Each side was cleansed for five-seCONDS using the sonic cleansing device with sensitive brush head or manually, using equal amounts of water and a gel cleanser. Photographs (VISIA-CR, Canfield Imaging, NJ, USA) were taken at baseline (before application of the SPM), after application of SPM (pre-cleansing), and following cleansing. Image analysis (Image), NIH, Bethesda, MD, USA was used to quantify colour intensity (amount of particulate pollutants on the typical of human sebum) using a scale of 0 to 255 (0 = all black pixels; 255 = all white pixels). Differences between the baseline and post-cleansing values pixels) are reported as the amount of SPM remaining following each method of cleansing.

RESULTS: Using a robust cleansing protocol to assess removal of pollutants (SPM; atmospheric particulate matter trapped in grease/oil), the sonic brush removed significantly more SPM than manual cleansing (P < 0.001). While extreme in colour, this pollution method easily allows assessment of efficacy through image analysis.

Background
Atmospheric pollutants of major public health concerns include particulate matter [soot or carbon black, dust (iron oxides)], carbon monoxide, ozone, nitrogen dioxide and sulphur dioxide. The US Environmental Protection Agency (EPA) and the World Health Organization (WHO) have summarized the global extent of common atmospheric pollutants as well as the hundreds of studies that...
have investigated their impact upon environmental and human health [1, 2]. Health effects most commonly recognized of critical concern include those associated with respiratory, cardiovascular and neurological diseases as well as allergies and cancer.

The impact of pollutants on skin health is most directly linked to allergic contact dermatitis; however, the long-term effect of tobacco smoke on skin ageing itself is, perhaps, most significant. Smoking tobacco is known to modulate production of inflammatory mediators leading to poor wound healing, skin cancer, hair loss, reduced blood flow and loss of collagen and elastin fibres. Although studies of a more direct link of particulate pollution to skin ageing are in their infancy [3–6], Vierkoeetter et al [6] have recently assessed the association of particulate pollution with pigmented spots on the forehead and cheeks of 400 Caucasian women in the Ruhr district of Germany. In women aged 70–80, an increase in soot (0.5 × 10⁻³ m²) and particles from traffic was associated with 20% more pigment spots on forehead and cheeks than those in more rural communities with lower atmospheric carbon levels. The number of spots was 35% for those living within 100 m of high traffic areas. Fan et al [5] showed a negative impact of particulate pollutants on skin barrier integrity.

In the light of these recent findings, we have developed a sebum pollution model (SPM) to mimic particulate matter trapped in sebum and oils to create a very robust (difficult to remove) surrogate for dirty, polluted skin. The exaggerated level of dirt and oils is necessary for optimal contrast for image analysis and to allow maximum differentiation between cleansing formulas and methods (e.g. cleansing brushes). Previous models to study skin cleansing are few, either being too easily removed, use ingredients that are poorly defined and/or not readily available or utilize ingredients that are not approved for use on skin (e.g. vacuum filter dust) [7–9]. In real-life situations, dirty skin does not only result from the accumulation of soot and dust onto the skin’s surface but comprises natural skin by-products [decomposition products from cornification (cellular debris and lipids), sebaceous secretions, sebum and oils to create a very robust (difficult to remove) surrogate for dirty, polluted skin. This combination of natural and environmental grease and oils attracts and retains environmental dirt and/or particulate pollutants (soot and dust) on the skin’s surface and within the skin’s pores; this results in a material that is very difficult to remove with superficial cleansing/hygiene regimes.

Materials and methods

In this pollution model, we utilize particulate matter (PM; Fig. 1) in the range of PM₁₀ and PM₂.₅ (having an aerodynamic diameter less than 2.5 μm and 10 μm, respectively) composed of carbon black (as a surrogate for soot) and iron oxides (as a surrogate for mineral dust). This surrogate for dirty skin (SPM – sebum, soil and pollutants) was developed using the key components of sebum [10] (e.g. squalane (as a more stable substitute for squalene), wax esters, triglycerides, fatty acids, cholesterol), applied product (natural and synthetic wax esters and oil) and particulate pollutant surrogates (e.g. iron oxides, carbon black) (Table I). This model is sufficiently robust in its adherence to the skin to mimic dirty skin at extreme levels to better aid in evaluation of the cleansing efficacy and synergies between cleansing devices and cleansing formulations. The evaluation tests are non-invasive tests using photographs and image analysis software to quantify the cleansing efficacy of various cleansing devices, cleansers and/or their combination.

Twenty subjects between the ages of 18 and 65 with informed consent were enrolled in a single-centre, cleansing study to compare the sonic cleansing brush (Clarisonic®), Pacific Bioscience Laboratories Inc., Redmond, WA, USA) to manual cleansing. Subjects laid on a spa chair in a supine position. An aesthetician wiped the apples of both cheeks with a 5-cm square gauze damped with alcohol to remove any residual make-up or debris. The area was allowed to dry (5 min). Circles 3.17 cm (1.25 inch) in diameter were drawn on the apples of both cheeks. Baseline photographs were taken (VISIA-CR, Canfield Imaging, NJ). Equal amounts of the sebum pollution model [SPM: 0.025 mg (3.2 μg cm⁻²)] were applied evenly with a gloved middle finger to the defined treatment region of each cheek (left and right) using moderate pressure and several clockwise and counterclockwise motions to ensure adherence of the

![Image](Image 311x542 to 535x700)

**Figure 1** Illustration reproduced from the US EPA showing the relative size of particulate matter (PM₂.₅ and PM₁₀) compared to reference particles (sand, pollen, fine beach sand).

**Table I** Composition of the sebum pollution model (SPM)

| INCI       | Cas#  | Grams |
|------------|-------|-------|
| Polyglyceryl Oleate | 9007-48-1 | 2.5   |
| Cholesterol | 57-48-5 | 3.5   |
| Squalane   | 111-01-3 | 7     |
| Oleic Acid | 112-80-1 | 15    |
| Glycerin Tritoate | 122-32-7 | 15    |
| Cetyl Palmitate | 540-10-9 | 8     |
| Mineral Oil | 8042-47-5 | 10    |
| Petrolatum | 8009-03-8 | 10    |
| Water      | 7732-18-5 | 20    |
| Carbon Black (CI 77266) | 1332-86-4 | 4     |
| Iron Oxides (CI 77492) | 1332-37-2 | 4     |

Preservative (CI 1) 1
Total 100
SPM to the skin. In previous cleansing studies (using natural sebum and artificial sebum formulas), we have repeatedly found that the SPM model has greater adhesion to the skin than both natural and artificial sebum (data not shown). Pre-cleansing photographs were taken.

The method of cleansing (sonic vs. manual) was randomized to the side of the face (left or right) for each subject. Prior to cleansing, each cheek was misted with water (~0.6 mL of water on the cheek area), and 0.5 mL of cleanser was applied to the centre of the cheek to be cleansed. The aesthetician dampened the brush head by placing in water (shaking off the excess), or for manual cleansing dampened index, middle and ring fingers. The aesthetician cleansed the designated area on the right cheek for 5 s (per cleansing method identified in the randomization schedule). Using 2 damp pieces of 10 x 10 cm gauze, the study aesthetician gently blotted the cleansed area twice to remove excess cleanser and dislodged SPM. The aesthetician repeated the same steps on the opposite cheek. Post-cleansing photographs were taken. Image analysis (ImageJ, NIH, Bethesda, MD, USA) was then used to quantify colour intensity (amount of particulate pollutants on the skin) using a scale of 0 (all black pixels) to 255 (all white pixels). Differences between the baseline and post-cleansing values (pixels) are reported as the amount of SPM remaining on the skin for each cleansing method (Table II).

## Results

The sonic cleansing brush removed significantly more SPM from the cheek than manual cleansing (P < 0.001, Table II). The data suggest that the sonic brush is better able to remove atmospheric particulate pollutants and sebum/oils typical of human sebum than manual cleansing. The sonic cleansing brush cleansed significantly better (less SPM remaining on the skin than post-manual cleansing; Fig. 2 and Table II).

## Conclusion

An increasing body of evidence suggests that air pollution not only negatively impacts systemic health but skin health as well. Atopic dermatitis, skin barrier damage, hyperpigmentation and other signs of skin ageing may be impacted by exposure to excessive amounts of air pollution and particulate matter. Besides limiting exposure where possible, a gentle and effective cleansing routine followed by appropriate use of moisturizers and sunscreens may limit skin damage associated with overexposure. In this study, we have provided an exaggerated, yet sensitive method to assess cleansing product efficacy on the removal of ‘particulate pollutants’ trapped in sebum and oils on the skin surface. In addition, we have shown that a sonic cleansing brush is more effective than manual cleansing at removing this trapped debris from the skin surface.

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References

1. WHO Regional Office for Europe. Health Effects of Particulate Matter: Policy Implications for Countries in Eastern Europe, Caucasus and Central Asia. World Health Organization (WHO) (2013).

2. U.S. EPA. Final Report: Integrated Science Assessment for Particulate Matter. U.S. Environmental Protection Agency, Washington, DC, EPA/600/R-08/139F (2009).

3. Goldsmith, L.A. Skin effects of air pollution. Otolaryngol. Head Neck Surg. 14, 217–219 (1996).

4. Krutmann, J., Liu, W., Li, L., Pan, X., Crawford, M., Sore, G. and Seite, S. Pollution and skin: from epidemiological and mechanistic studies to clinical implications. Dermatol. Sci. 76, 163–168 (2014).

5. Pan, T.L., Wang, P.W., Aljuffali, I.A., Huang, C.T., Lee, C.W. and Fang, J.Y. The impact of urban particulate pollution on skin barrier function and the subsequent drug absorption. J. Dermatol. Sci. 78, 51–60 (2015).

6. Vierkotter, A., Schikowski, T., Ranft, U., Sugiri, D., Matsui, M., Kramer, U. and Krutmann, J. Airborne particle exposure and extrinsic skin aging. J. Invest. Dermatol. 130, 2719–2726 (2010).

7. Schrader, K. On the Problems of In Vivo Cleansing of the Human Skin. In: Cosmetics: Controlled Efficacy Studies and Regulation (Elsner, P., Merk, H.F. and Maibach, H.I., eds.), pp. 92–106. Springer-Verlag, Berlin (1999).

8. Schrader, K. and Rohr, M. Methods for measuring the skin-cleansing effect of surfactants in comparison with skin roughness and compatibility. Clin. Dermatol. 14, 57–64 (1996).

9. Wolf, R. and Friedman, M. Measurement of the skin-cleaning effects of soap. Int. J. Dermatol. 35, 598–600 (1996).

10. Valiveti, S., Wesley, J. and Lu, G.W. Investigation of drug partition property in artificial sebum. Int. J. Pharm. 346, 10–16 (2008).