**“The 12 Principles of 'Green Chemistry for Medical Labs' Explained” – Kelly Nijhof, UMC Utrecht, K.M.Nijhof-4@umcutrecht.nl**

Translated and supplemented by the UCL LEAF Team and Kelly Nijhof, read the original article in Dutch here.

| # | Principle | Application in Medical Laboratory |
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| 1 | Waste Prevention | Use accurate volumes, work with micro-analytical techniques to reduce waste.<br><br>UCL LEAF: Scale down work to optimise a protocol before scaling back up if needed |
| 2 | ‘Maximise atom efficiency’<br>(i.e. how do we get the *most* out of the *least* amount of raw materials)<br><br>Adapted from ‘Atom Economy’ | Choose methods that convert as much of the reactants as possible into the desired product [or make the most out of the sample you have]<br><br>For example,<br>- Use of multi-test platforms where one sample enables multiple analyses<br>- Minimising sample and reagent volumes in PCR and ELISA<br>- Avoid unnecessary repeat measurements through accurate pipetting and calibration<br>- Good planning of batch analyses to avoid wastage of kits and time |
| 3 | to ‘Use fewer hazardous substances’<br><br>Adapted from ‘Less hazardous chemical synthesis’ | Use less toxic reagents for example using ethanol instead of methanol<br><br>UCL LEAF: Other examples including replacing Ethidium Bromide with SYBR Safe and GelRed® for DNA visualisation, using water based clearing solutions instead of solvent based ones (also relevant to Principle 5). |
| 4 | Designing safer chemicals | Select test kits with lower toxicity and minimal health risks |
| 5 | Safer solvents and auxiliaries (additives) | Preferably use water, buffer solutions or ethanol as a solvent, and avoid volatile or toxic substances |
| 6 | Design for energy efficiency | Use energy -efficient appliances and work at room temperature if possible<br><br>UCL LEAF:<br>- Change your PCR hold temperature to 12C instead of 4C, or even higher. Read this miniPCR blog for more info: https://www.minipcr.com/four-degree-myth-pcr-stability/ (Source from Kelly Nijhof)<br>- Purchase goods that can be shipped and stored at higher temperatures (e.g. room temp instead of fridge, fridge instead of -20C, -20C instead of -70/-80C) and really consider what the evidence-based storage temperature of your items are. |

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| | | - Consider innovative techniques such as DNA caching that allows for long term room temperature storage, although consider new methods may not have had a full LCA performed. |
| 7 | Use of renewable feedstocks | Choose reagents of biological original such as enzymes or biopolymers<br><br>UCL LEAF:<br>- Consider buying biobased 'drop-in replacements' for solvents (same chemical, biobased source) such as biobased (bb) ethanol, bb Acetone, bb 2-Propanol, bb Ethyl Acetate (Merck/Sigma Aldrich, 2025)<br>- Where the chemical properties allow, consider using biobased alternatives (different/safer chemical, biobased source) such as bb Cyrene™ to replace NMP and DMF, 2-bb Methyltetrahydrofuran to replace Tetrahydrofuran , and bb Ethyl(-)-L-lactate to replace Ethyl Acetate and Acetone, for more information visit Sigma Aldrich*: https://www.sigmaaldrich.com/GB/en/campaigns/biorenewable-solvents or Search: Sigma Aldrich Biorenewable<br>- Consider buying biobased plastics, these are made from renewable feedstocks instead of fossil-fuel based feedstocks but are often still the same polymer so provide the same properties needed. Whilst the plastic may be biobased it's not necessarily biodegradable, and often the waste stream will be the same as non-biobased plastics, especially if contaminated with biohazards and chemical hazards. The benefit of biobased lies in the reduced carbon impact of producing the plastic.<br><br>*Note: This is not an endorsement, rather a "this is what exists" and other companies may offer the same or equivalent products. |
| 8 | Reduce derivatives<br><br>Derivatisation: a chemical process in which a compound is converted into another (derived) compound (derivative), usually to improve detection, increase stability or volatility, or improve reactivity. | Limit non-invasive chemical steps and use direct analysis methods<br>Instead of derivatisation to make a substance detectable via gas chromatography (GC) you can:<br>1. Switch to liquid chromatography (LC-MS) which can often be done without derivatisation<br>2. Choose reagents or methods with lower toxicity or fewer steps<br>3. Use biomarkers that can be directly analysed if possible |
| 9 | Catalysis | Use enzymatic reactions, such as ELISA, instead of chemical reactions with excess reagents |
| 10 | Design for degradation | Choose reagents [and consumables] that are biodegradable so that waste is less harmful |
| 11 | 'Real-time pollution monitoring' | Monitor processes live, such as temperature and pH, to prevent errors or overuse of chemicals |

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| | Adapted from ‘Real-time pollution prevention’ | |
| 12 | ‘Safer working practices to avoid accidents’<br><br>Adapted from ‘Safer chemistry for accident prevention’ | Avoid explosive or flammable substances and work in safe conditions with [suitable and sufficient control measures] and appropriate PPE. |