# Environmental Management Systems & Operator Performance at Sites Regulated under Integrated Pollution Control

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**Statement of Use**
This report will influence the Environment Agency policy on the role of environmental management systems in regulation, expressed through schemes such as the Operator Performance Risk Appraisal (OPRA) Methodology used for IPPC. In addition, it should provide focus for the EU LIFE-Environment funded REMAS project, that aims to demonstrate the benefits of externally verified environmental management systems in the regulatory process.

**Keywords**
Environmental Management Systems, Integrated Pollution Control, environmental management systems.

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# EXECUTIVE SUMMARY

This report assesses how the status, with respect to externally validated environmental management systems (EMS), of sites regulated under Integrated Pollution Control (IPC) affects operator performance and compliance records. The analysis is based on a survey recording the EMS status of 843 IPC sites, the Agency's Operator and Pollution Risk Appraisal (OPRA) records, and records of enforcement action.

It was concluded that having an externally validated EMS, certified to the international standard ISO 14001 or registered under the European Union's Eco-Management and Audit Scheme (EMAS), is associated with higher levels of operator performance overall, but that this is restricted to the procedural aspects of performance, such as recording and use of information, plant maintenance and management and training. EMS sites are neither more nor less likely to suffer from incidents, complaints or non-compliance events than those without. They are also neither more nor less likely to be subject to enforcement action. Other findings were that sites with an EMS tend to improve their operator performance more quickly than those without, and sites registered under EMAS tend to perform better than those certified to ISO 14001.

# CONTENTS

# 1 INTRODUCTION

This report assesses possible links between the performance of sites regulated under Integrated Pollution Control (IPC) and their status with regard to externally validated environmental management systems (EMS). The report is one output from a wider project considering the possibility of extending risk-based regulation to take account of whether a site is either certified to the international EMS standard ISO 14001 or registered with the EU Eco-Management and Audit Scheme (EMAS). Risk-based regulation could lead to the better targeting of regulatory resources so as to secure maximum environmental benefits.

The report focuses on IPC because the authorisation and enforcement regime is believed to resemble the certification/registration procedures for EMS more than is the case for water or waste regulation. The report is based on statistical evidence drawn from several datasets held by the Environment Agency.

At an initial stakeholder workshop held in March 2002[1], there was a broad stakeholder consensus that EMS needed to deliver real improvements in performance if they were to contribute to risk-based regulation. The view of some was that the key performance indicator was the legal compliance record of the sites concerned. Others took the view that broader measures of environmental performance could be considered. It was recognised that environmental performance is an ill-defined concept which might cover regulated emissions and releases, aspects of environmental performance not covered by legislation, and even attitudes to the environment.

This report addresses both the legal compliance record of IPC sites and "operator performance" as assessed by EA field inspectors as a proxy for broader environmental performance. Ideally, environmental performance could be measured in terms of releases to the environment and associated rates of improvement. However, because the EU MEPI project had generated limited evidence using this type of indicator, and because the data processing demands were greater, it was decided to focus on operator assessment indicators. The statistical analysis casts light on the following questions:

1) is an externally validated EMS associated with higher levels of operator performance as assessed by field inspectors?

2) is an externally validated EMS associated with particular aspects of operator performance?

3) is an externally validated EMS associated with faster rates of improvement in operator performance?

4) are sites with an externally validated EMS more or less likely to be subject to enforcement action?

5) are sites subject to enforcement action assessed differently in terms of operator performance?

[1] K Dahlström and J Skea, *Modernising Regulation: The Role of Environmental Management Systems. Report of a scoping workshop held at the PSI Conference Centre, London 15 March 2002*. May 2002.

# 2 DATA SOURCES

The analysis involved three separate datasets which were linked using IPC process authorisation codes as a unique identifier:

1) a survey of the EMS status of IPC sites conducted for the EA by AEAT[2];

2) a database containing OPRA (Operator and Pollution Risk Appraisal) scores for IPC sites; and

3) records of enforcement action taken by the EA during the period November 1999 – October 2001.

The EA had also commissioned a study which cleaned up these datasets and prepared them for use[3].

**EMS survey**

The basis for the analysis was a survey-generated dataset containing information on the EMS status of 843 sites regulated under the IPC regime. AEAT sent the survey questionnaire to 1279 sites, generating a 66% response. An important question is whether, as a result of self selection, the respondents to the survey have characteristics significantly different from those of IPC sites in general. We tested the pattern of OPRA scores for respondents vis-à-vis those of all IPC sites and found no statistically significant difference[4] (Appendix A). It was therefore concluded that respondents were representative of IPC operators in general. The subsequent analysis is based on this assumption. In conducting the analysis, sites covered by the survey were divided into three groups according to their EMS status: a) those with no externally validated EMS; b) those with ISO 14001; and c) those with EMAS. In general, we tested for significant differences between these three groups.

[2] AEAT, *EMS Survey of IPC Operators*, AEAT/ENV/R/0699, April 2001

[3] I Housley, *Effectiveness of Management Systems – Review of Environment Agency Data*, R&D Technical Report P6-017, CTC Environmental, March 2002

[4] In testing for statistical significance throughout this report, we have tested the hypothesis that the means from two or more samples are equal and taken from populations with the same mean. We performed analyses of statistical variance (ANOVA tests) which calculate the F-statistic, i.e. the ratio of the mean square *between* samples to the mean square *within* samples. The selected significance value for all tests is 0.05, meaning there is a 5% chance of rejecting a true hypothesis. If the obtained value of F is greater than the critical F, the result is statistically significant and it is possible to reject the hypothesis that the means are equal and from the same population.

## The Operator And Pollution Risk Appraisal (OPRA) system

The Environment Agency OPRA system, devised as a move toward risk-based regulation, is intended to provide a basis for planning inspection activities and frequencies, by assessing both the inherent risk of a process and the ability of the operator to manage that risk. The Operator Performance Appraisal (OPA) and the Pollution Hazard Appraisal (PHA) are both scoring exercises, with enforcement officers awarding a score of between 1 and 5 in a range of different factors, or attributes, with 1 representing low performance/hazard and 5 high performance/hazard (see box below).

### Box 2.1 OPRA Operator Performance and Pollution Hazard Appraisal attributes

| **Operator Performance Attributes** | **Pollution Hazard Attributes** |
|---|---|
| 1. Recording and use of information<br>2. Knowledge and implementation of authorisation requirements<br>3. Plant maintenance<br>4. Management and training<br>5. Process operation<br>6. Incidents, complaints and non-compliance events<br>7. Recognised environmental management systems (ISO 14001 or EMAS) | 1. Presence of hazardous substances<br>2. Scale of hazardous substances<br>3. Frequency of nature of hazardous operations<br>4. Technologies for hazard prevention and minimisation<br>5. Technologies for hazard abatement<br>6. Location of process<br>7. Offensive characteristics |

Environmental management systems are already given some recognition in this system. Currently, a site with ISO 14001 certification achieves a score of three for the OPA 7 attribute and a site with both ISO 14001 and EMAS gets a score of five. A score of two could be awarded if a site is working toward EMS certification.

OPA attributes 1 to 5 all concern process issues reflecting the general managerial capacity at a site. Attributes 1 to 5 are related to each other, in the sense that a higher score on one attribute can be used to predict a higher score on any other attribute. OPA 6 refers to incidents and complaints. It is the only attribute in the operator assessment reflecting "outcomes" or "the environmental track record of the process"[5], rather than procedural issues. OPA 6 is very weakly correlated with the first 5 attributes and it is not possible to predict a higher OPA 6 score on the basis of any of these (see Appendix B).

The Agency's database of OPA scores contained 4500 records covering 1700 separate IPC processes. The scores were assigned by enforcement officers during the period 1999-2001. Individual sites might have been assessed more than once over this period.

[5] Environment Agency, *Operator and Pollution Risk Appraisal (OPRA)*. Version 2, August 1997, p. 15.

The comparable database of PHA scores contained 3600 records. It is possible that companies operating more hazardous processes might be more likely to implement a formal EMS. We tested this by comparing the distribution of PHA scores for companies with EMAS, ISO 14001 or no externally validated system. EMAS sites were found to have significantly higher mean PHA scores than other sites. However the difference was only two points and we did not investigate this further. There was however no statistically significant difference in PHA scores for sites with and without ISO 14001 (Appendix C, D).

**Enforcement records**

A list of 1100 enforcement actions taken between November 1999 and October 2001[6] was obtained and converted into a database format. The actions included both enforcement notices and court action. Only 129 of the enforcement actions referred to IPC processes. We were able to identify the IPC authorisation codes associated with most of these and hence link this relatively small sample with the other datasets.

[6] Environment Agency (2001), *EA Prosecutions: Waste and PIR. 1 November 1999 to 31 October 2001.*

# 3 EXTERNALLY VALIDATED EMS AND OPERATOR PERFORMANCE

We compared the most recent total OPA scores for sites with EMAS, ISO 14001 and no externally validated EMS. As shown below, mean OPA scores are significantly better for sites with externally validated EMS than for those without. EMAS registered sites have higher scores than sites certified to ISO 14001. The differences in means are statistically significant as well as substantial (see Appendix E).

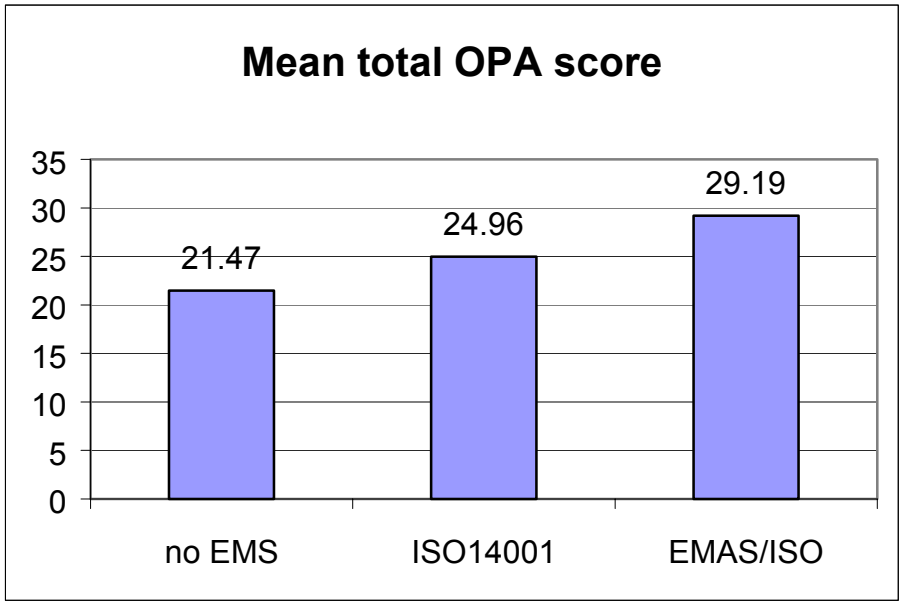



**Figure 3.1 Mean total OPA score by type of EMS**

The differences in means between the subgroups remain significant (see Appendix F) even when the total OPA score is adjusted to remove the points awarded under OPA 7, which is the attribute giving recognition to externally validated EMS.

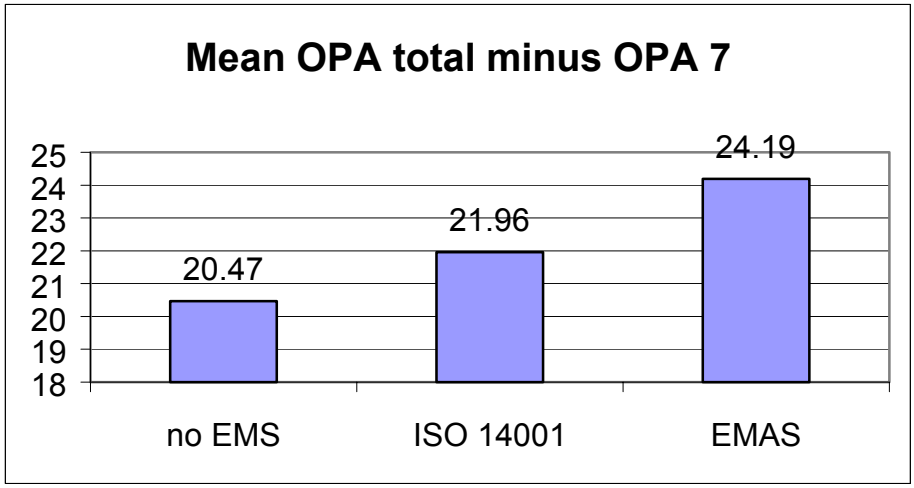



**Figure 3.2 Mean total OPA score minus OPA 7 by type of EMS**

The distributions of OPA scores are also relevant. The three histograms below show that there are fewer poor performers, as judged by overall lower total OPA scores, among the groups with externally validated environmental management systems. The theoretical range of total OPA scores is 0 to 35. The sites without an externally validated EMS had a range of scores from 9 to 31 points, while ISO 14001 certified sites scored between 14 and 33 points. No EMAS-registered site scored less than 20, the highest reached the maximum score of 35.

***Conclusions:***

- ***Environmental management systems are associated with better operator performance, as indicated by higher total OPA scores.***

- ***EMAS sites are associated with higher levels of performance than sites with ISO 14001.***

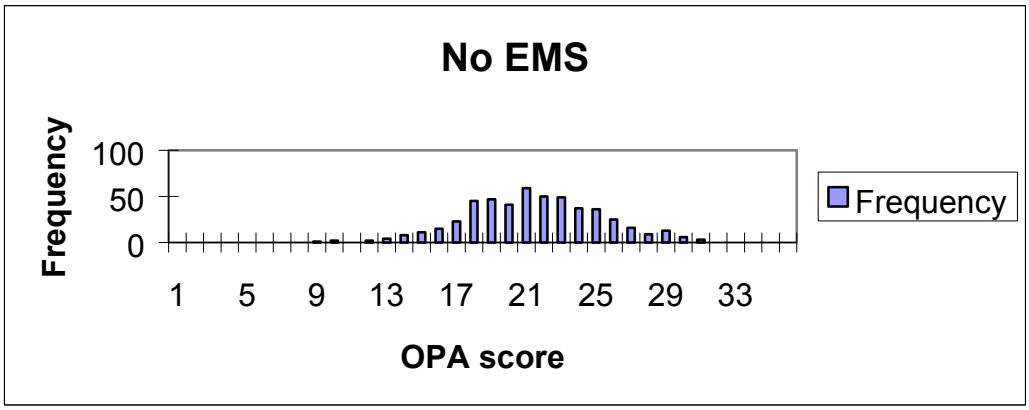



**Figure 3.3 Distribution of OPA scores: Sites with no externally validated EMS**

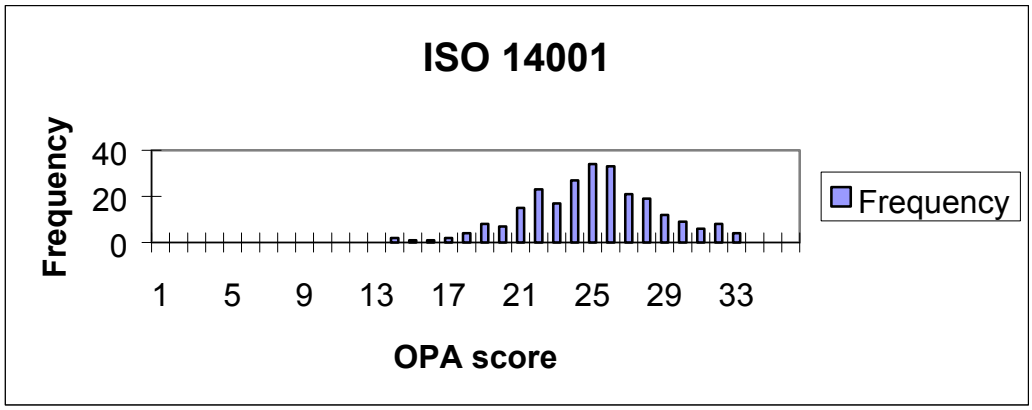



**Figure 3.4 Distribution of OPA scores: Sites with ISO 14001**

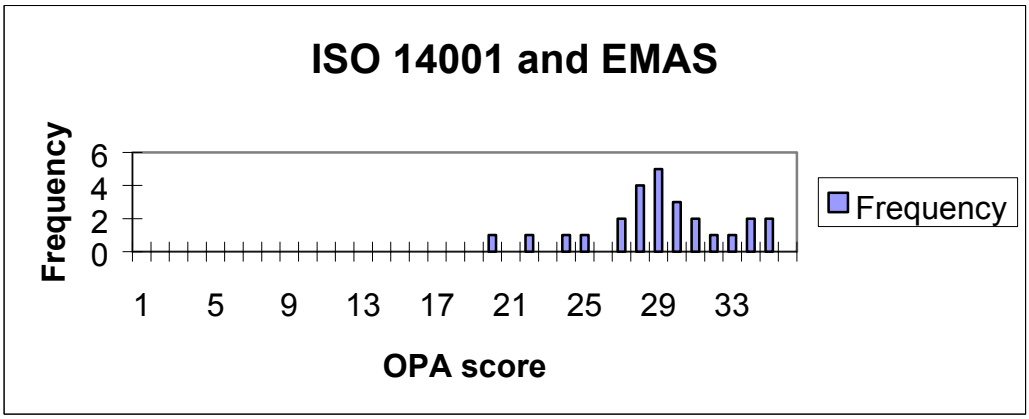



**Figure 3.5 Distribution of OPA scores: Sites with ISO 14001 and EMAS**

# 4 EMS AND PARTICULAR ASPECTS OF OPERATOR PERFORMANCE

As shown below, we found that sites with an externally recognised EMS tend to have higher scores for the following OPA attributes (see Appendix G):

- recording and use of information;
- knowledge and implementation of authorisation requirements;
- plant maintenance;
- management and training; and
- process operation.

Again, EMAS sites performed better than sites certified only to ISO 14001, which in turn performed better than sites with neither of these systems. This is perhaps unsurprising, given that these attributes reflect issues that a management system is intended to improve.

On the other hand, OPA 6, the outcome attribute related to incidents, complaints and non-compliance events, did not show statistically significant differences between sites with EMAS, ISO 14001 or no EMS (see Appendix H).

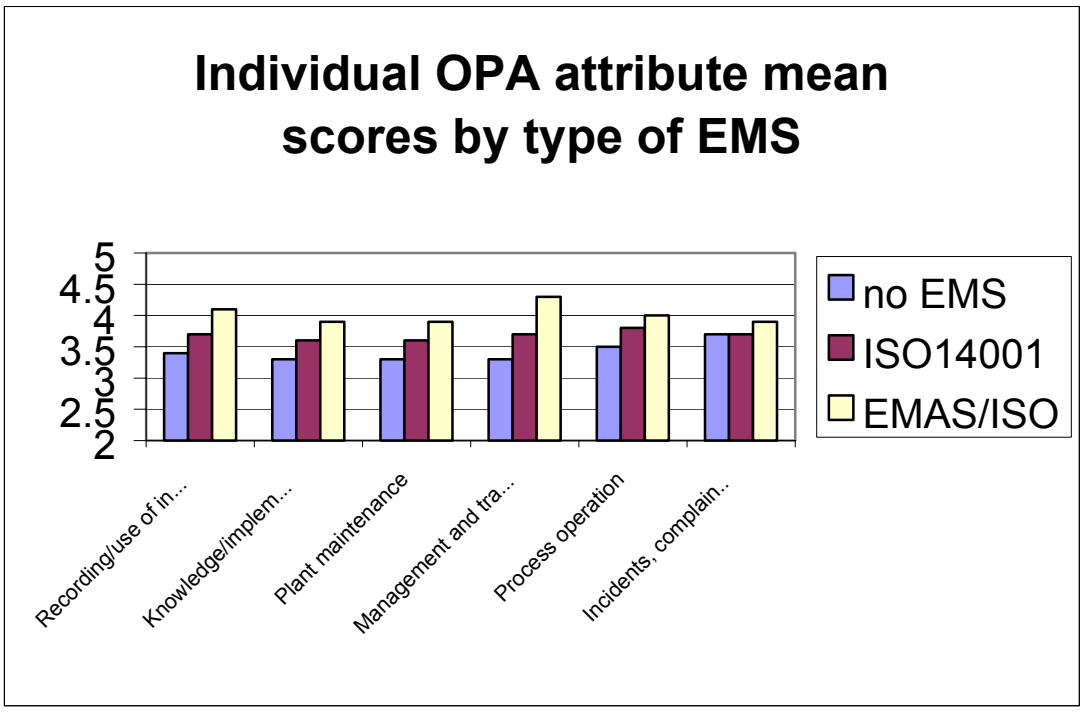



**Figure 4.1 Individual OPA attribute mean scores by type of EMS**

***Conclusions:***

- ***Environmental management systems are associated with higher levels of operator performance in relation to most aspects of process management…***

- ***…but environmental management systems do <u>not</u> appear to be associated with a lower likelihood, as assessed by field inspectors, of incidents, complaints and non-compliance events.***

# 5 EMS AND CONTINUOUS IMPROVEMENT

One of the goals of an EMS is to promote continuous improvement in environmental performance. We attempted to measure improvement for sites which had had their OPA scores assessed on more than one occasion, by comparing the first and last OPA scores in the database. The difference between the first and last scores was then divided by the intervening time period to obtain a normalised annual rate of OPA improvement. First and last OPA scores assessed less than a year apart were ignored because the short time interval led to some extreme annual rates of improvement. This left just over 400 sites with the OPA scores assessed, on average, 18 months apart.

The diagram below shows that 39.4% of the sites had no change in their OPA scores, while 46.4% experienced an improvement and 14.2% a deterioration. The shape of the distribution is normal, except for the disproportionately large number of cases with static scores, suggesting that OPRA scores have not been amended as frequently as would be expected. Sites showing no change in OPA scores were also removed from the analysis.

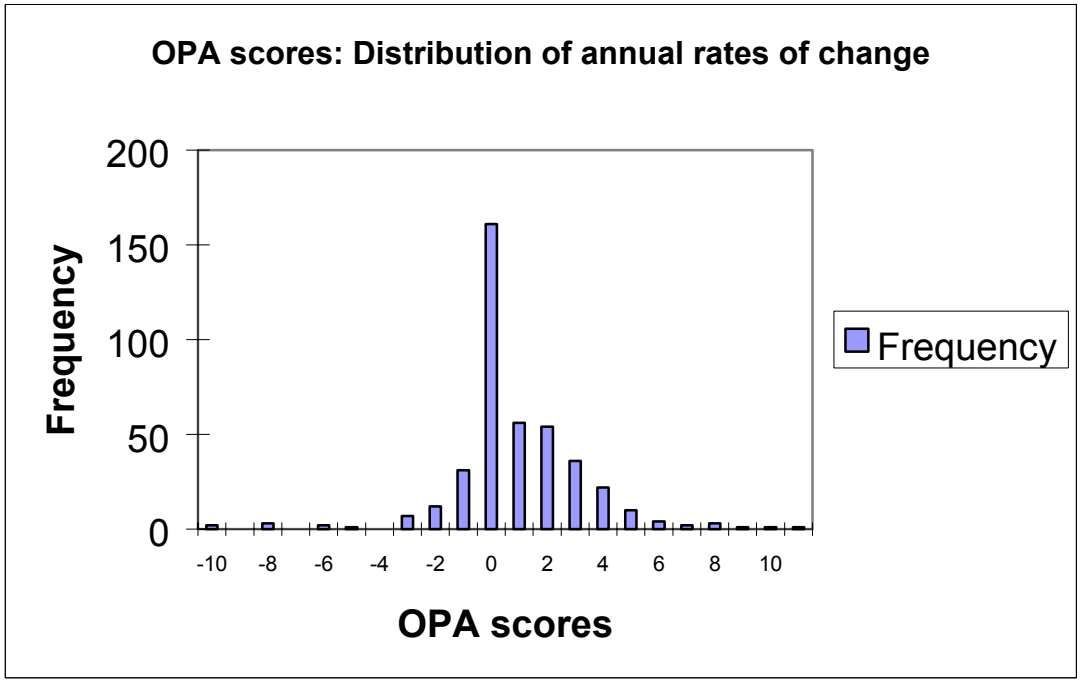



**Figure 5.1 OPA scores: Distribution of annual rates of change**

The next graph shows that the presence of an EMS has an impact on the rate of improvement of OPA scores. Sites with either ISO 14001 or EMAS started from a higher baseline than those without an externally validated EMS and also improved more rapidly. The average annual rates of improvement in OPA points were 0.56 for EMAS sites, 1.00 for ISO 14001 sites and 0.26 for sites with no EMS (Appendix I). Although the more rapid rate of improvement for ISO 14001 is statistically significant, it is not possible to conclude that ISO 14001 is "better" than EMAS at inducing continuous improvement. EMAS-registered sites started from a higher baseline and hence had less scope for improvement.

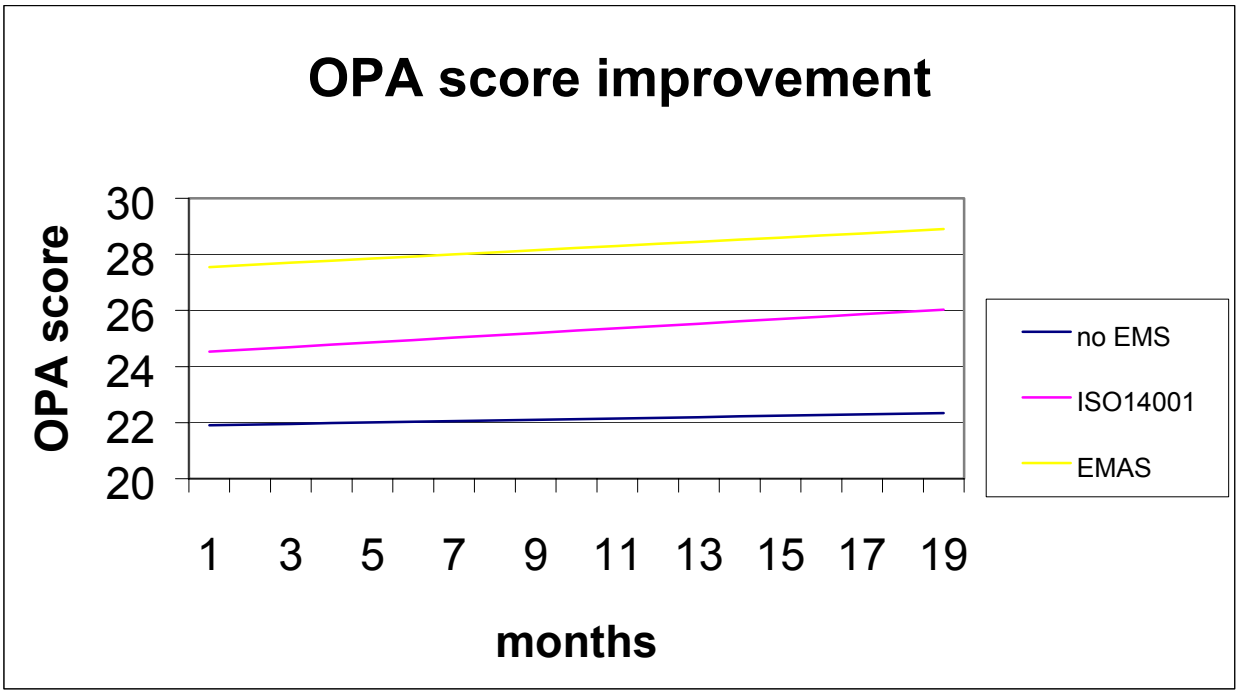



**Figure 5.2 Comparative OPA score improvements**

***Conclusions:***

- ***Sites with externally validated EMS tend to show more rapid rates of improvement, as measured by OPA scores, than those without;***

- ***There is no conclusive evidence to show that EMAS is better at inducing continuous improvement than ISO 14001, or vice versa.***

# 6 EMS AND ENFORCEMENT ACTION

From a regulatory perspective, legal compliance is a key aspect of environmental performance. We therefore took IPC sites subject to enforcement action and compared their EMS status with that of IPC sites more generally. Although there are 129 sites in the enforcement data set, it was possible to link only 55 of these to the EMS dataset, which is in itself only a sample of all IPC sites.

Taking into account the relatively small sample size, there is no statistical evidence that sites with an externally validated EMS are more or less likely to be subject to enforcement action than those without (Appendix J). As can be seen in the figure below, ISO 14001 sites are slightly "under-represented" in the enforcement dataset, while the seven EMAS sites are significantly "over-represented". However, it is very difficult to draw conclusions from such small numbers. Although the seven processes covered by EMAS are associated with only three companies, this does indicate that no environmental management system can provide an absolute guarantee of legal compliance. The seven actions associated with EMAS sites involved six court cases, two of which resulted in fines, and one enforcement notice.

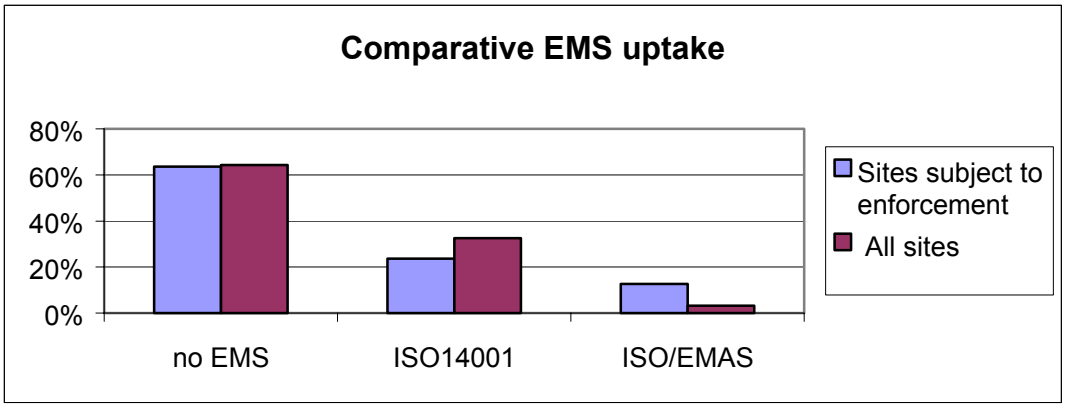



**Figure 6.1 Comparative EMS uptake: Sites subject to enforcement and all sites**

***Conclusion:***

- ***Sites with an externally validated EMS are no more or no less likely to be subject to enforcement action than those without.***

# 7 OPERATOR PERFORMANCE AND ENFORCEMENT ACTION

We compared the scores for individual OPA attributes of sites subject to enforcement action with those for all IPC sites. There were statistically significant differences between sites subject to enforcement action and others in respect of OPA attributes 1 to 6 (Appendix K), with sites subject to enforcement action obtaining lower scores. However, the differences were very small with regard to OPA attributes 1 to 5, but larger with regard to OPA 6. As the figure below shows, enforcement officers have assigned significantly lower scores for OPA 6 (complaints, nuisances and non-compliance) to sites subject to enforcement action. The average OPA 6 score for sites subject to enforcement was 2.9 and for all sites 3.8. This finding can be read as validating the judgments of the enforcement officers in relation to OPA 6, although it might also mean that enforcement officers have taken compliance history of the site into account when scoring OPA6.

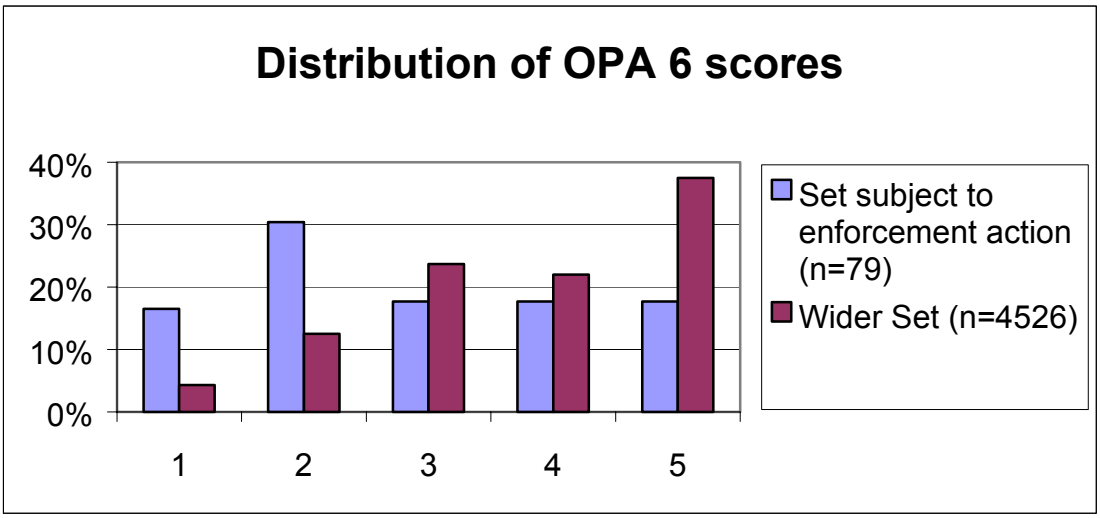



**Figure 7.1 Distribution of OPA 6 scores: Sites subject to enforcement action and all sites**

***Conclusions:***

- ***The differences in OPA scores relating to process/management issues are small between sites subject to enforcement action and IPC sites more generally;***

- ***on average, field inspectors assign lower scores for OPA 6 (complaints, nuisances and non-compliance) to sites which are subject to enforcement action.***

# 8 SECTORAL VARIATIONS

We attempted to analyse whether any of the links between EMS status, operator performance and compliance records varied from one type of industrial process to another. We were unable to identify any such variations, partly because the findings were not statistically significant and partly because there were insufficient number of records (especially on enforcement) referring to individual process types.

# 9 CONCLUSIONS

The data analysis shows a clear pattern of association between the EMS status of sites, assessments of operator performance and compliance status. As shown below, there is a strong association between EMS status and OPA attributes 1 to 5 broadly representing management/process issues. There is also a strong association between OPA 6, relating to complaints, nuisances and the perceived likelihood of non-compliance, and actual compliance status. But there is no statistically significant link between these two separate bundles of attributes.

The specific conclusions from the data analysis are:

- sites with an externally validated EMS tend to have higher levels of operator performance;
- EMAS registered sites are associated with higher levels of performance than those certified to ISO 14001;
- sites with externally validated EMS tend to have higher levels of operator performance with respect to process/management issues such as recording and use of information, knowledge and implementation of authorisation requirements, plant maintenance, management and training, and process operation…
- …but they do not have a lower likelihood, as assessed by enforcement officers, of suffering from incidents, complaints and non-compliance events;
- sites with externally validated EMS tend to show more rapid rates of improvement in operator performance than those without;
- there is no conclusive evidence to show that EMAS is better at inducing continuous improvement than ISO 14001, or vice versa;
- sites with an externally validated EMS are no more or no less likely to be subject to enforcement action than those without;
- sites subject to enforcement action perform somewhat more poorly with respect to process/management issues;
- sites subject to enforcement action are assessed more poorly by field inspectors in terms of their likelihood of experiencing complaints, nuisances and non-compliance events.

There are two main conclusions that can be drawn from these findings.

First, the clear association between the procedural aspects of operator performance and externally validated environmental management systems suggests that there could be synergies between the procedural aspects of EMS certification/registration and environmental regulation. There are potential links in terms of monitoring and measurement, as well as between the authorisation process on the one hand and the process of certification/registration on the other.

Second, the analysis came up with no evidence that an externally validated EMS leads to *direct* improvements in outcomes, as measured either by OPA 6 scores in the operator performance assessment, or by the legal compliance record. Therefore, reducing the degree of inspection for compliance at sites with EMAS or ISO 14001 is unlikely to lead to a better targeting of resources.

# 10 RECOMMENDATIONS

**Environment Agency data holdings**

Refining and extending this sort of analysis would be facilitated by some changes in the way the Environment Agency collects and holds data. The Environment Agency could make better use of its data by ensuring that all relevant details of enforcement (company names, addresses, dates etc.) are recorded on the national database (in addition to paper records). Consistency in aggregation would facilitate this sort of survey work and the ability to more easily relate the data to external data sets held by other bodies.

The introduction of a unique site identifier would greatly increase the ability to link the many different sorts of data currently collected by the Environment Agency.

**Further research**

Various pieces of research could cast further light on the potential links between regulation and EMS:

- the work in this paper could be extended to cover waste and water regulation as well as IPC;
- other indicators of operator performance could be explored, specifically actual levels of environmental releases and associated rates of improvement to supplement field inspectors' subjective assessments;
- a more systematic exploration of variations in performance between different classes of regulated process (e.g. combustion v. chemicals) could be explored.

## List of Figures

# Appendix A

## Analysis of statistical variance: OPA scores

| *Groups* | *Count* | *Sum* | *Average* | *Variance* | | |
|---|---|---|---|---|---|---|
| OPA_wider set | 4526 | 103486 | 22.86478 | 19.43674 | | |
| OPA with EMS information | 782 | 17872 | 22.85422 | 18.00433 | | |
| *Source of Variation* | *SS* | *df* | *MS* | *F* | *P-value* | *F crit* |
| Between Groups | 0.074375 | 1 | 0.074375 | 0.003868 | 0.950408 | 3.843212 |
| Within Groups | 102012.6 | 5306 | 19.2259 | | | |
| Total | 102012.7 | 5307 | | | | |

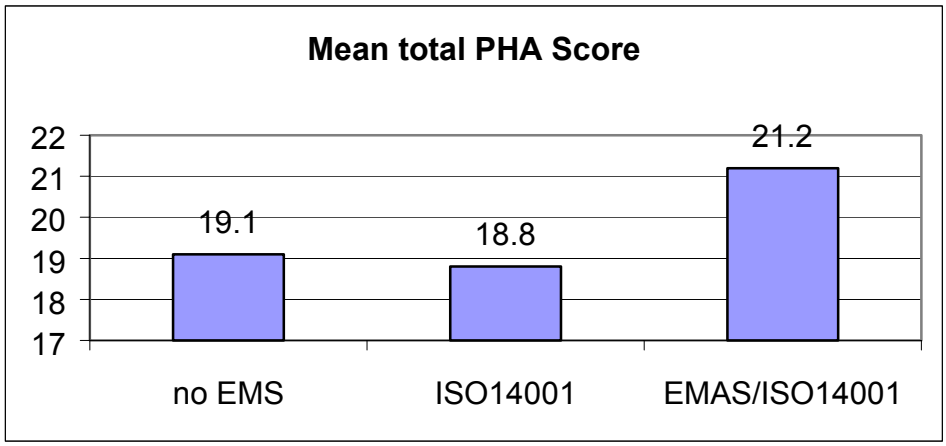
# Appendix B

## Correlation between OPA Attributes

| | *OPA1 Recording* | *OPA2 Knowledge* | *OPA3 Maintenance* | *OPA4 Management* | *OPA5 Operations* | *OPA6 Incidents* |
|---|---|---|---|---|---|---|
| OPA1 Recording | 1 | | | | | |
| OPA2 Knowledge | 0.522194 | 1 | | | | |
| OPA3 Maintenance | 0.460559 | 0.458353 | 1 | | | |
| OPA4 Management | 0.569632 | 0.527945 | 0.560207 | 1 | | |
| OPA5 Operations | 0.479315 | 0.444544 | 0.495793 | 0.507891 | 1 | |
| OPA6 Incidents | 0.233763 | 0.251286 | 0.226976 | 0.242812 | 0.281383 | 1 |

# Appendix C

## Mean total PHA Score



# Appendix D

## Analysis of statistical variance: PHA scores

| *Groups* | *Count* | *Sum* | *Average* | *Variance* | | |
|---|---|---|---|---|---|---|
| PHA total ISO 14001 | 197 | 3709 | 18.82741117 | 16.34761214 | | |
| PHA total no EMS | 390 | 7464 | 19.13846154 | 14.11445521 | | |
| *Source of Variation* | *SS* | *df* | *MS* | *F* | *P-value* | *F crit* |
| Between Groups | 12.66351238 | 1 | 12.66351238 | 0.852035497 | 0.356357691 | 3.857394404 |
| Within Groups | 8694.655057 | 585 | 14.86265822 | | | |
| Total | 8707.318569 | 586 | | | | |

| *Groups* | *Count* | *Sum* | *Average* | *Variance* | | |
|---|---|---|---|---|---|---|
| PHA total no EMS | 390 | 7464 | 19.13846154 | 14.11445521 | | |
| PHA total EMAS | 19 | 403 | 21.21052632 | 13.50877193 | | |
| *Source of Variation* | *SS* | *df* | *MS* | *F* | *P-value* | *F crit* |
| Between Groups | 77.78602101 | 1 | 77.78602101 | 5.521568205 | 0.019260326 | 3.864414566 |
| Within Groups | 5733.680972 | 407 | 14.08766824 | | | |
| Total | 5811.466993 | 408 | | | | |

| *Groups* | *Count* | *Sum* | *Average* | *Variance* | | |
|---|---|---|---|---|---|---|
| PHA total ISO 14001 | 197 | 3709 | 18.82741117 | 16.34761214 | | |
| PHA total EMAS | 19 | 403 | 21.21052632 | 13.50877193 | | |
| *Source of Variation* | *SS* | *df* | *MS* | *F* | *P-value* | *F crit* |
| Between Groups | 98.41382927 | 1 | 98.41382927 | 6.109309119 | 0.014227409 | 3.885276101 |
| Within Groups | 3447.289874 | 214 | 16.10883119 | | | |
| Total | 3545.703704 | 215 | | | | |

# Appendix E

## Analysis of statistical variance: OPA Score by type of EMS

| *Groups* | *Count* | *Sum* | *Average* | *Variance* | | |
|---|---|---|---|---|---|---|
| no EMS | 503 | 10799 | 21.46918 | 14.52046 | | |
| ISO 14001 | 253 | 6316 | 24.96443 | 13.1773 | | |
| EMAS | 26 | 759 | 29.19231 | 12.32154 | | |
| *Source of Variation* | *SS* | *df* | *MS* | *F* | *P-value* | *F crit* |
| Between Groups | 3135.968 | 2 | 1567.984 | 111.8759 | 1.95E-43 | 3.007287 |
| Within Groups | 10917.99 | 779 | 14.01539 | | | |
| Total | 14053.96 | 781 | | | | |

# Appendix F

## Analysis of statistical variance: OPA scores minus OPA 7

| *Groups* | *Count* | *Sum* | *Average* | *Variance* | | |
|---|---|---|---|---|---|---|
| no EMS | 503 | 10296 | 20.46918 | 14.52046 | | |
| ISO14001 | 253 | 5557 | 21.96443 | 13.1773 | | |
| EMAS | 26 | 629 | 24.19231 | 12.32154 | | |
| *Source of Variation* | *SS* | *df* | *MS* | *F* | *P-value* | *F crit* |
| Between Groups | 637.4058 | 2 | 318.7029 | 22.73949 | 2.52E-10 | 3.007287 |
| Within Groups | 10917.99 | 779 | 14.01539 | | | |
| Total | 11555.4 | 781 | | | | |

# Appendix G

## Individual OPA attribute scores by type of EMS

| OPA Attribute | Average OPA Score | | |
|---|---|---|---|
| | No EMS (n=503) | ISO 14001 (n=253) | EMAS (n=26) |
| 1. Recording and use of information | 3.4 | 3.7 | 4.1 |
| 2. Knowledge and implementation of authorisation requirements | 3.3 | 3.6 | 3.9 |
| 3. Plant maintenance | 3.3 | 3.6 | 3.9 |
| 4. Management and training | 3.3 | 3.7 | 4.3 |
| 5. Process operation | 3.5 | 3.8 | 4.0 |
| 6. Incidents, complaints and non-compliance events | 3.7 | 3.7 | 3.9 |

# Appendix H

## Analysis of statistical variance: Individual OPA scores

| *Groups* | *Count* | *Sum* | *Average* | *Variance* | | |
|---|---|---|---|---|---|---|
| no EMS OPA1 | 503 | 1694 | 3.367793 | 0.6792 | | |
| ISO 14001 OPA1 | 253 | 924 | 3.652174 | 0.592823 | | |
| EMAS OPA1 | 26 | 107 | 4.115385 | 0.666154 | | |
| *Source of Variation* | *SS* | *df* | *MS* | *F* | *P-value* | *F crit* |
| Between Groups | 24.31246 | 2 | 12.15623 | 18.67779 | 1.19E-08 | 3.007287 |
| Within Groups | 507.0034 | 779 | 0.650839 | | | |
| Total | 531.3159 | 781 | | | | |

| *Groups* | *Count* | *Sum* | *Average* | *Variance* | | |
|---|---|---|---|---|---|---|
| no EMS OPA2 | 503 | 1659 | 3.298211 | 0.875037 | | |
| ISO 14001 OPA2 | 253 | 910 | 3.596838 | 0.78126 | | |
| OPA2 Knowledge | 26 | 101 | 3.884615 | 0.586154 | | |
| *Source of Variation* | *SS* | *df* | *MS* | *F* | *P-value* | *F crit* |
| Between Groups | 20.95988 | 2 | 10.47994 | 12.54437 | 4.34E-06 | 3.007287 |
| Within Groups | 650.7997 | 779 | 0.83543 | | | |
| Total | 671.7596 | 781 | | | | |

| *Groups* | *Count* | *Sum* | *Average* | *Variance* | | |
|---|---|---|---|---|---|---|
| no EMS OPA3 | 503 | 1646 | 3.272366 | 0.692601 | | |
| ISO 14001OPA3 | 253 | 900 | 3.557312 | 0.604837 | | |
| EMAS OPA3 | 26 | 102 | 3.923077 | 0.553846 | | |
| *Source of Variation* | *SS* | *df* | *MS* | *F* | *P-value* | *F crit* |
| Between Groups | 21.41983 | 2 | 10.70992 | 16.23311 | 1.24E-07 | 3.007287 |
| Within Groups | 513.951 | 779 | 0.659757 | | | |
| Total | 535.3708 | 781 | | | | |

| *Groups* | *Count* | *Sum* | *Average* | *Variance* | | |
|---|---|---|---|---|---|---|
| no EMS OPA4 | 503 | 1652 | 3.284294 | 0.693916 | | |
| ISO 14001 OPA4 | 253 | 927 | 3.664032 | 0.668423 | | |
| EMAS OPA4 | 26 | 112 | 4.307692 | 0.541538 | | |
| *Source of Variation* | *SS* | *df* | *MS* | *F* | *P-value* | *F crit* |
| Between Groups | 44.46704 | 2 | 22.23352 | 32.65893 | 2.4E-14 | 3.007287 |
| Within Groups | 530.3271 | 779 | 0.680779 | | | |
| Total | 574.7941 | 781 | | | | |

| *Groups* | *Count* | *Sum* | *Average* | *Variance* | | |
|---|---|---|---|---|---|---|
| no EMS OPA5 | 503 | 1776 | 3.530815 | 0.647953 | | |
| ISO 14001 OPA5 | 253 | 958 | 3.786561 | 0.605057 | | |
| EMAS OPA5 | 26 | 105 | 4.038462 | 0.598462 | | |
| *Source of Variation* | *SS* | *df* | *MS* | *F* | *P-value* | *F crit* |
| Between Groups | 15.48744 | 2 | 7.74372 | 12.24327 | 5.82E-06 | 3.007287 |
| Within Groups | 492.7082 | 779 | 0.632488 | | | |
| Total | 508.1957 | 781 | | | | |

| *Groups* | *Count* | *Sum* | *Average* | *Variance* | | |
|---|---|---|---|---|---|---|
| no EMS OPA6 | 503 | 1869 | 3.715706 | 1.482761 | | |
| ISO 14001 OPA6 | 253 | 938 | 3.70751 | 1.302999 | | |
| EMAS OPA6 | 26 | 102 | 3.923077 | 1.753846 | | |
| *Source of Variation* | *SS* | *df* | *MS* | *F* | *P-value* | *F crit* |
| Between Groups | 1.120988 | 2 | 0.560494 | 0.391049 | 0.67648 | 3.007287 |
| Within Groups | 1116.548 | 779 | 1.433309 | | | |
| Total | 1117.669 | 781 | | | | |

# Appendix I

## OPA score improvements by type of EMS

| Status of Sites | Mean Annual OPA Score Rate of Change (18-month period) | Average OPA Start Score | Average OPA End Score |
|---|---|---|---|
| No externally verified EMS (n=263) | 0.26 | 21.9 | 22.3 |
| ISO 14001 (n=129) | 1.00 | 24.5 | 26.0 |
| EMAS and ISO 14001 (n=17) | 0.56 | 27.55 | 28.9 |

# Appendix J

## Comparative EMS uptake

| EMS Status | Sites subject to Enforcement Action (n=55) | Wider Set (n=782) |
|---|---|---|
| No externally validated EMS | 63.6% | 64.3% |
| ISO 14001 | 23.6% | 32.4% |
| EMAS and ISO 14001 | 12.7% | 3.2% |

# Appendix K

## Analysis of statistical variance: OPA scores of sites subject to enforcement action

| *Groups* | *Count* | *Sum* | *Average* | *Variance* | | |
|---|---|---|---|---|---|---|
| OPA 1 enforcement | 79 | 244 | 3.088608 | 0.979228 | | |
| OPA 1total | 4526 | 15666 | 3.461335 | 0.731212 | | |
| *Source of Variation* | *SS* | *df* | *MS* | *F* | *P-value* | *F crit* |
| Between Groups | 10.78682 | 1 | 10.78682 | 14.66768 | 0.00013 | 3.843482 |
| Within Groups | 3385.113 | 4603 | 0.735415 | | | |
| Total | 3395.9 | 4604 | | | | |

| *Groups* | *Count* | *Sum* | *Average* | *Variance* | | |
|---|---|---|---|---|---|---|
| OPA 2 enforcement | 79 | 249 | 3.151899 | 0.745862 | | |
| OPA 2 total | 4526 | 15264 | 3.372514 | 0.814131 | | |
| *Source of Variation* | *SS* | *df* | *MS* | *F* | *P-value* | *F crit* |
| Between Groups | 3.779067 | 1 | 3.779067 | 4.648449 | 0.031133 | 3.843482 |
| Within Groups | 3742.118 | 4603 | 0.812974 | | | |
| Total | 3745.897 | 4604 | | | | |

| *Groups* | *Count* | *Sum* | *Average* | *Variance* | | |
|---|---|---|---|---|---|---|
| OPA 3 enforcement | 79 | 238 | 3.012658 | 0.781889 | | |
| OPA 3 total | 4526 | 14901 | 3.292311 | 0.746138 | | |
| *Source of Variation* | *SS* | *df* | *MS* | *F* | *P-value* | *F crit* |
| Between Groups | 6.072263 | 1 | 6.072263 | 8.131659 | 0.004369 | 3.843482 |
| Within Groups | 3437.26 | 4603 | 0.746743 | | | |
| Total | 3443.332 | 4604 | | | | |

| *Groups* | *Count* | *Sum* | *Average* | *Variance* | | |
|---|---|---|---|---|---|---|
| OPA 4 enforcement | 79 | 239 | 3.025316 | 0.691659 | | |
| OPA 4 total | 4526 | 15427 | 3.408529 | 0.717266 | | |
| *Source of Variation* | *SS* | *df* | *MS* | *F* | *P-value* | *F crit* |
| Between Groups | 11.40224 | 1 | 11.40224 | 15.90643 | 6.76E-05 | 3.843482 |
| Within Groups | 3299.58 | 4603 | 0.716833 | | | |
| Total | 3310.982 | 4604 | | | | |

| *Groups* | *Count* | *Sum* | *Average* | *Variance* | | |
|---|---|---|---|---|---|---|
| OPA 5 enforcement | 79 | 244 | 3.088608 | 0.851022 | | |
| OPA 5 total | 4526 | 16149 | 3.568051 | 0.679456 | | |
| *Source of Variation* | *SS* | *df* | *MS* | *F* | *P-value* | *F crit* |
| Between Groups | 17.8479 | 1 | 17.8479 | 26.156 | 3.28E-07 | 3.843482 |
| Within Groups | 3140.92 | 4603 | 0.682364 | | | |
| Total | 3158.768 | 4604 | | | | |

| *Groups* | *Count* | *Sum* | *Average* | *Variance* | | |
|---|---|---|---|---|---|---|
| OPA6 enforcement | 79 | 229 | 2.898734 | 1.861409 | | |
| OPA 6 total | 4526 | 17012 | 3.758727 | 1.442327 | | |
| *Source of Variation* | *SS* | *df* | *MS* | *F* | *P-value* | *F crit* |
| Between Groups | 57.42513 | 1 | 57.42513 | 39.61915 | 3.37E-10 | 3.843482 |
| Within Groups | 6671.72 | 4603 | 1.449429 | | | |
| Total | 6729.145 | 4604 | | | | |